ETI

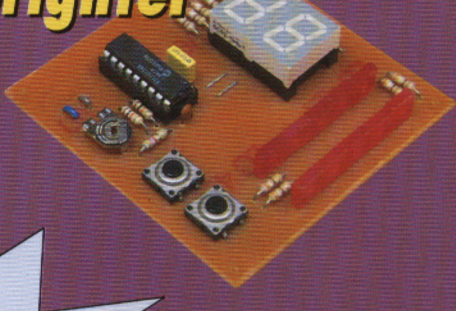
47 68 71
73
64
66

ELECTRONICS
TODAY INTERNATIONAL

5 RD RESEARCH SPICE PACKAGES TO WIN!

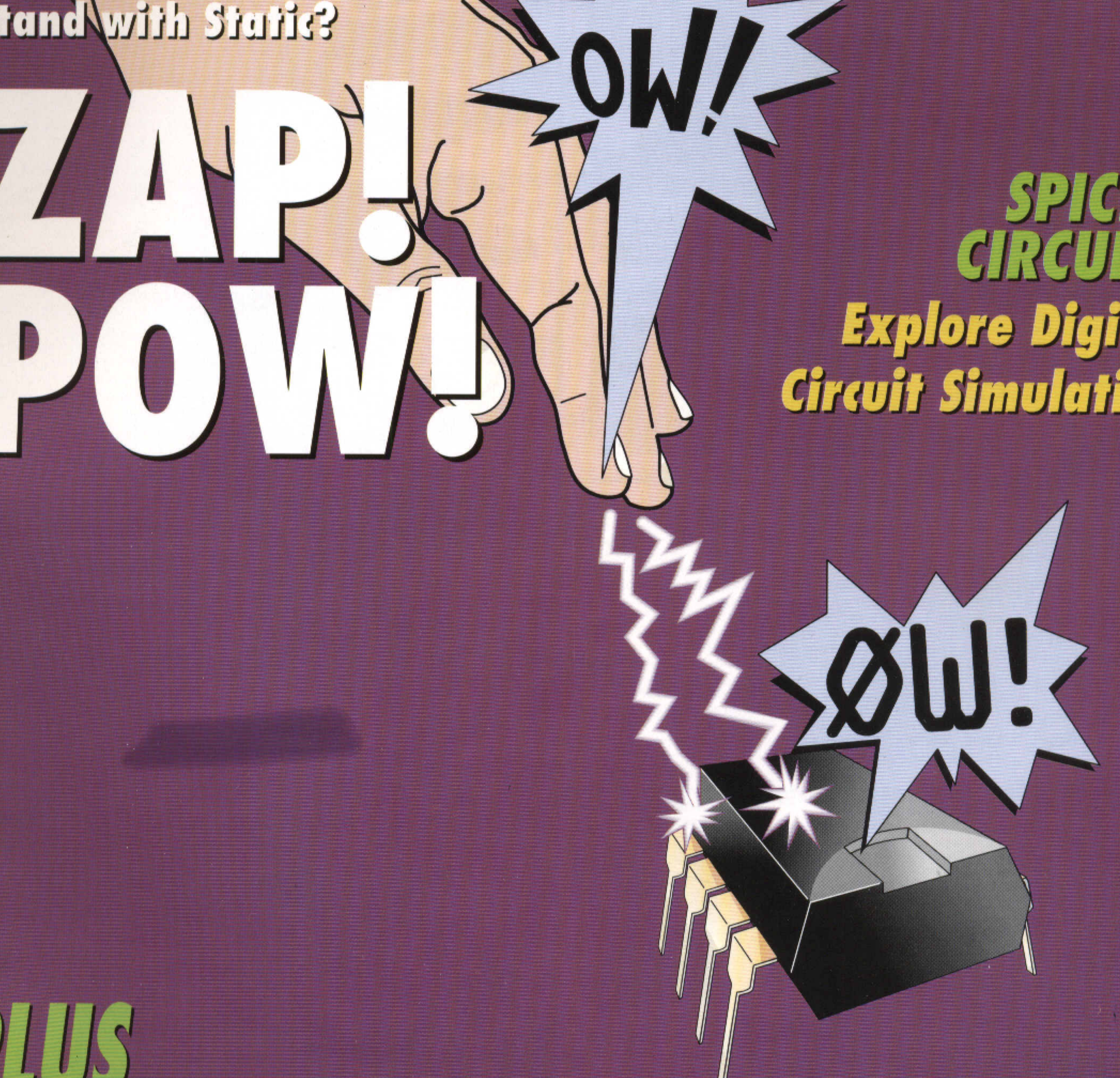
PIC DRIVEN IQ TESTER

The faster you move, the brighter you are!



Where do we Stand with Static?

ZAP! POW!



SPICED CIRCUITS

Explore Digital Circuit Simulation

PLUS

Valve Characteristic Tester

Controlling DC Motors

9 770142 722153 10

FOR ENTHUSIASTS BY ENTHUSIASTS
NEXUS

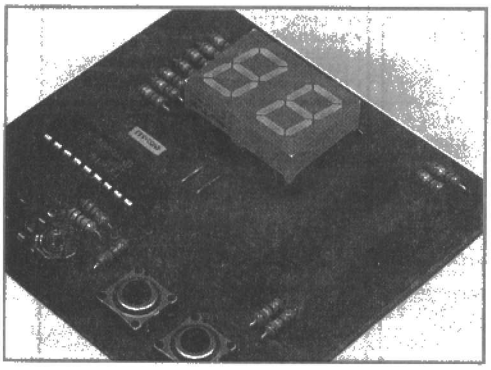
Vol 26 Issue: 10 12 September 1997 £2.50
USA $4.95

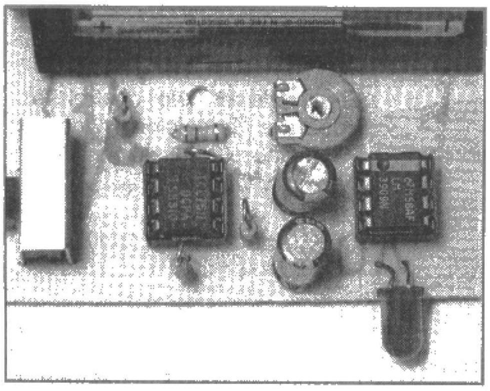
Contents

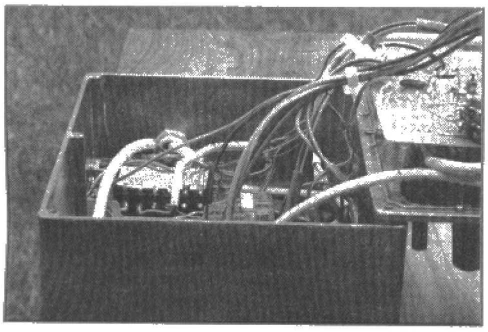
Volume 26 No.10

& Features Projects

Next Issue 10th October 1997







Win One of 5 Powerful Computer Circuit Modelling Packages! 8

Answer three SPICE questions and you are in with a chance of one of our B2 SPICE prizes from RD Research. Start here with simulation!

Electrostatics in Electronics 13

How safe is your MOS chip? The attraction between oppositely charged particles in disparate materials has been a source of wonders, inventions and disasters. John Linsley Hood explains what really happens.

PIC-driven IQ Tester 19

Scientists have shown that there is a correlation between ability to concentrate and the intelligence measured by IQ. Bart Trepak's PIC program and IQ tester gives you a chance to try it out.

Higher Education Special (Part 3) 29

In the last part of our education round-up: Diplomas in Hull, day release in Huddersfield and study, American-style, in London.

Valve Characteristic Tester (Part 2) 35

Peter Kenyon's continues and concludes his design for a portable Valve Characteristic Tester with all the constructional details, component layouts and parts list, including the PCB Service.

Speed Control in DC Motors (Part 2) 47

In the second and final part, David Ponting extends his search for a constant drive to his DC motor under varying loads, to find a variety of standard running speeds for his reel to reel tape recorder.

Win one of 5 Software Packages! 51

RD Research and ETI bring you an exclusive competition to win a selection of RD Research's latest SPICE Software for electronic circuits.

Mock Alarm Flasher 57

If you don't want to leave your Pink Floyd CDs on your dashboard, you could consider this handy flashing-LED car-alarm lookalike by Terry Balbirnie. It's cheap, too.

Spiced Circuits (Part 4): Going Digital 64

Part 4 of Owen Bishop's series using SPICE-based software to discover circuit simulation continues this month with the introduction to digital circuits. Now to consign the resistors and op amps to the spares box and get out the logic ics!

Ham Radio Today 71

All the best for Radio Amateurs

Regulars

News 8, 10

ETI PCB Service 66

PCB foils 68, 71

Practically Speaking 73

Terry Balbirnie goes into light emitting diodes

Round the Corner 74

☎

SUBSCRIPTIONS
& BACK ISSUES HOTLINES:
01858 435344
ORDERS:
ENQUIRES:
01858 435322
Lines Open 9am - 6.30pm

Subscribe & Save

Phone the hotline and take advantage of our special offer detailed on page 44

ETI ELECTRONICS TODAY INTERNATIONAL News...

ETI SPECIAL OFFER! SHARING PCB PROTOTYPE COSTS

10% off Save 10% on your next PCB Pool Order®.

For this once only offer send Beta LAYOUT the Promotional card attached to the front cover with your next order, to qualify for a 10% reduction on the price of your PCB.

Beta LAYOUT Ltd, based in Ennis Co, Clare has established in the British Isle's first PCB pooling service. The aim is to offer customers a cost effective solution to their prototyping needs. Due to the high cost of set-up tooling and photo-plotting, buying one board can work out almost as expensive as buying 5, 10 or even more, depending on the size of the PCB.

WHAT IS THE PCB-POOL®? We all know the problem. Many new designs flounder due to high prototype costs. This is not necessary. Beta LAYOUT has come up with the answer. "THE PCB-POOL®". A pooling principal which allows designers to share the costs.

HOW? The answer is simple. Several designs are placed together on a multi-panel. The high set-up costs charged by the manufacturer to cover machine costs are shared by all participating PCB-POOL partners. So now each designer gets a super price. For example, the price of one Eurocard including tooling, photoplot and VAT is only £49.

EXPRESS SERVICE Beta LAYOUT have a fast turnaround service in 5 and 7 working days. The standard delivery time is 15 working days.

This new way of ordering has proved itself in Germany where over 2000 customers use the PCB-POOL for their prototypes. Beta LAYOUT relies on well known PCB suppliers all over Europe, resulting in top quality, industry standard, Printed Circuit Boards. So why not give it a try, the next time you need a low cost prototype. And save a lot of money!

The Hot line for technical questions is: 00353 (65) 66500. For more Info call 00353 (65) 66500. Fax: 66514.

OFTEL and BT Internet progress for schools

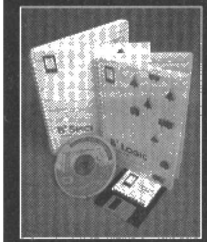
OFTEL has started a consultation period, involving the telecommunications industry and schools, on BT's proposals to wire up schools to on-line services including the Internet as soon as possible. The proposals were submitted in May. The OFTEL Director General, Donald Cruikshank, stated that OFTEL's approach would provide schools with access to the Internet at predictable and affordable prices, and allow them the choice of Internet Service Provider.

The cable industry launched its own proposed package for connecting schools to the Internet in January. OFTEL expects to make a statement on its conclusions in September or soon afterwards.

President of the Board of Trade Margaret Beckett said, "Realising the Government's commitment to wire up schools to advanced on-line services as quickly as possible is an objective in which everyone has a common interest. We must ensure that children have access to such services so that their future employability is increased. The plan to have agreement in the coming academic year is testimony to the commitment that all the interested parties have in achieving the Government's objective."

David Plunkett, Secretary of State for Education and Employment, said, "In our White Paper, Excellence for Schools, we reaffirmed our commitment to create a National Grid for Learning, an unprecedented Internet-based educational resource. I welcome both today's proposals, and the spirit of partnership in which they are made, as an integral step to achieving this." The Secretary of State was referring to the Government's election manifesto promise that "We have agreed with BT and the cable companies that they will wire up schools, libraries, colleges and hospitals to the information superhighway free of charge. We have also secured agreement to make access charges as low as possible."

SPICE at a lower price



RD Research's new low-cost B2 Spice Lite at £49.95 plus VAT is based on the widely-used professional B2 Spice V2, Spice Lite enables electronics designers to build and test circuits on their computers using industry-standard Spice software. The new B2 Spice Lite is aimed at people who wish to use electronics CAD for circuit simulation, but do not need some of the more advanced analysis features found in more expensive software.

B2 Spice Lite is available in PC or Mac formats and features drag-and-drop components which can be connected to each other. The circuit built up on the screen can then be tested, measured or analysed in a number of ways.

Paul Williamson of RD Research says, "We want to provide industry standard design software that everyone with a computer and an interest in electronics will use. Making it affordable is the important first step. With B2 Spice Lite we have made that first step easy and, as with all our software, it is offered on a full 30-day trial period."

The minimum system requirements are a 386 PC (486 recommended) with 8MB ram or a full specification Mac. It is compatible with Windows 95NT or Windows 3.1 with 8MB of ram.

For further information contact RD Research Research House, Norwich Road, Eastgate, Norwich NR10 4HA. Tel. 01603 872331 email rd.research@paston.co.uk Web site: www.paston.co.uk/spice

OVERSEAS READERS

To call UK telephone numbers, replace the initial 0 with your local overseas access code plus the digits 44.

Power from Poultry goes for Prizes!

Paul Apps, a Chartered Engineer with London-based firm Fibrowatt Ltd., has reached the National Final of the 1997 Environment Award for Engineers through his work to generate electricity from poultry litter.

About 2 million tonnes of poultry litter is produced annually by the UK poultry industry. As readers with a general scientific background will have deduced, it is bacterially active nitrogenous waste rich in ammonia - and it is difficult to dispose of. Undisposed manure rots, releasing carbon dioxide and methane - ever more socially unacceptable as greenhouse gases - attracts vermin and runs the risk of contaminating watercourses.

As a result of the project, there are now two power stations, Firbropower in Suffolk and Fibrogen in North Lincolnshire, turning poultry litter waste into electricity. Although the use of animal waste as a power source (including the use of methane-generating poultry waste to power automobiles) has been an area of investigation for decades, these power stations are the first of their kind in the world. Each burns 150 kilotonnes of poultry litter a year to power a steam-driven generator producing 13 megawatts. The electricity is passed into local networks.

One station provides power for about 12,000 homes. Dry ash residue from the process is sold as a slow-release phosphate-rich fertiliser. As a readily renewable source, using poultry waste helps to reduce the use of non-renewable fossil fuels. Sales are being developed in Italy, other Continental countries and Japan under licence.

Organised annually by the Engineering Council, the Environment Award for Engineers is sponsored by British Aerospace, BP, CIBSE, Lloyd's Register and the IEE. The top prize is £5,000 to the winning engineer, who will also receive the Lloyd's Register Trophy. Other finalists are David Martin of Lighting Electronics Ltd. for work on the development of electronic starters for fluorescent lamps, Ian Coutts of ABB Power Generation Ltd. as project manager of South Humber Bank Power Station, and Stefan Croft-Bednarski , Raymond Daniels and Simon Harbord for work on the successful removal and disposal of four Viking A offshore gas platforms from the UK sector of the North Sea.

£3.5 million in grants for electronics projects

Fifteen innovative IT (information technology) and electronics projects have won grants totalling up to £3.5M under the Government's Sector Challenge, announced recently by Margaret Beckett, President of the Board of Trade.

The projects were designed by nationally representative trade associations and other business, research and training organisations to improve efficiency and competitiveness in their sectors. The grants will support projects worth £9.7M.

Winners within the IT and electronics sector include the Federation of the Electronics Industry with a grant of £130,000 to extend overseas marketing opportunities for small and medium sized firms; £500,000 to the Science Research Foundation to support a £2.6M European Microelectronics Design Centre and a further £33.750 to the Federation of the Electronics Industry for the Top Technician in Industrial Electronics Contest 1998.

The 186 winning projects were selected from a field of over 600 bids, and will be over three years, subject to a contract worked out with the Government.

An opportunity not to miss

Did you know that there is an organisation which has 30,000 research assistants at your disposal?

Members with creative ideas - they've done it - not just talked about it!
Valuable resource information *including*:
EMC advice
Propagation forecasting
Technical data
Recruitment adverts

Plus, a comprehensive list of specialist publications and much, much more!

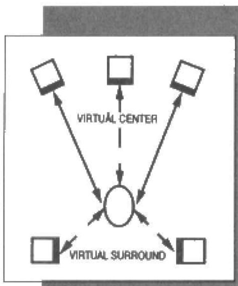
As a member you would receive RadCom, the 100 page colour magazine delivered to your door every month

Who are we?
We are the national society for radio amateurs and if you are interested in electronics we can help you

RSGB

Radio Society of Great Britain (Dept ET19) Lambda House Cranborne Road Potters Bar Herts EN6 3JE
Tel: 01707 659015 Fax: 01707 645105;
e-mail: sales@rsgb.org.uk

ETI ELECTRONICS TODAY INTERNATIONAL News...



Dolby Surround Sound demo board

Medianix have produced a reference design and demonstration board, based on their MED25006 Virtual Dolby Surround processor ic. The EB25006-3 board enables digital audio developers to implement realistic 3D sound in systems that can deliver 3D sound from two ordinary stereo speakers for applications such as video games, PCs, television and stereo sound systems. This is seen as particularly useful in systems where building in more than two speakers would raise the price or increase the size of the system uneconomically.

The MED25006 has been fully tested and certified by Dolby Laboratories.

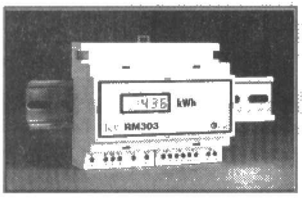
The demonstration board will be used as a reference design for original equipment manufacturers and software developers to test and design new applications. With the addition of an amplifier, speakers and the audio source, the board provides a complete 3D surround sound audio system. It is designed to plug-and-play, and does not require a PC interface or any digital signal processing (DSP) programming for implementation.

The board demonstrates the capability of the MED25006, an all-digital implementation of Virtual Dolby Surround which uses proprietary 24-bit DSP technology to process two-channel audio digitally into two-channel 3D surround sound (the effect of front and rear speaker pairs using only two actual speakers). The ic includes on-chip digital Dolby ProLogic decoding for surround sound systems originating with four channels plus a sub-woofer audio output, and Dolby's virtualising algorithms. It is capable of operating in fully digital Dolby Pro-Logic mode, Dolby 3 Stereo mode (with left, right and centre channels) and Virtual Dolby Surround mode, with mono to stereo synthesis. The chip also contains "sweet spot" adjustment to compensate for the placement of speakers relative to the listener.

For more information contact Medianix Semiconductor Inc., 100 View Street, Suite 101, Mountain View, California 94041, USA.

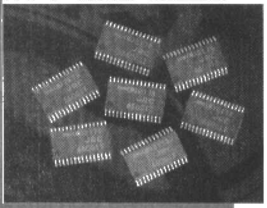
Electronic kWh meter

The RM303 is a DIN rail-mounting electronic kilowatt-hour meter. Traditional electro-mechanical kWh meters are still more familiar in most applications. The RM303 is a single-function meter with standard current transformer inputs (CTs) allowing connection to loads of a few watts to hundreds of megawatts. In the event of power failure to the meter, readings are stored for a minimum of 25 years. The meter has an optional pulse output suitable for Building Energy Management Systems, and can be combined with the manufacturer's Abacus meter/datalogger to provide a low-cost computerised energy management system.



For information contact Northern Design (Electronics) Ltd., 228 Bolton Rd., Bradford, W. Yorks BD3 0QW. Tel. 01274 729533.

Mitsubishi Dolby Sound Processor



Mitsubishi's M62460FP sound processor provides a single-chip route into Dolby ProLogic Surround Sound features, including centre and surround sound channel trimming for five-speaker systems from television to cinema applications, including satellite receivers.

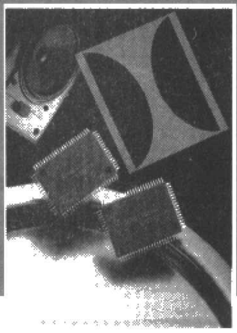
The analogue processor, licensed by Dolby Laboratories, has a Dolby Pro-Logic decoder, on-board memory and the I2C bus for cable television (CTV) applications. With a microcontroller interface, the chip provides Disco, Hall and Live modes and five delay time positions for digital space surround effects, as well as echo (Karaoke) effect with either 147.5ms short echo or 196.6ms long echo. Some people regard Karaoke as a mixed blessing, but the ones actually doing it always seem to have a lovely time.

The M62460FP is a BiCMOS solution designed to give improved sound performance compared to CMOS solutions and provide a higher-quality linear alternative to digital and mixed analogue/digital solutions. The on-board memory means space-saving and assembly advantages over two-chip solutions with external memory arrangements.

For more information contact Mitsubishi Electric Europe BV, Semiconductor Division, Travellers Lane, Hatfield, Herts AL10 8XB. Tel 01797 276100 Fax 01707 278837.

NJM2178 audio processor

An audio processor from Young-ECC regenerates 3D sound on two or more speakers from any audio source to provide a surround sound effect, restoring sound that is normally masked in stereo. The enhanced sound image from a stereo source, and the centre sound image, can be controlled separately. The NJM2178 SRS 3D audio processor has a wide operating power supply voltage from 4.7V to13V and requires a supply of 10 mA typically. The dynamic range is greater than 110dB and output noise typically less than -90dB.



For more information contact Young-ECC Electronics, Knaves Beech Industrial Estate, Loudwater, Bucks HP10 9QY.

Electrostatics in Electronics

Static electricity causes lightning, and is used in photocopiers. It is an interesting phenomenon which is not always well explained at school and university. John Linsley Hood explains what it is all about.

Two thousand six hundred years ago, in 590 BC or thereabouts, a Greek philosophical physicist called Thales, of Miletos - a once thriving Greek city on the western coast of Turkey - is said to have made the observation that amber, when rubbed vigorously with a dry cloth, acquired a new quality, in that it was able to attract, from a distance, small objects such as feathers or pieces of cork. In so doing, he gave a name to the branch of engineering which we pursue, in that "elektron" is the Greek word for amber.

Since the effects of electrostatic charges are such an important aspect of contemporary electronics technology, both usefully and destructively, it seems a curious paradox that the subject of Electrostatics tends now to be regarded as a rather exotic study, and is seldom touched on in science courses, except as a somewhat specialised postgraduate topic. At the end of the last century, when such effects weren't really useful for anything very much, the phenomena of static electrification were thought to be an important part of the study of physical sciences.

Admittedly, in the 1890s, there weren't so many other interesting things to study in Physics, and the orders of voltage that could be generated by Wimshurst machines, or stored in Leyden jars, were capable of some quite spectacular effects, to galvanise - if one might use the term - the most torpid of students.

My personal interest in this topic arises from the fact that although I am, by preference, an electronics engineer, I spent many years as a research physicist in the plastics films manufacturing industry, a field in which one needed to be familiar with the mechanisms involved in the generation of "static" in order to avoid the major problems, and discomforts, it could cause. Having, as it were, a foot in both camps, I often wish that an understanding of these phenomena could be more widely spread.

In reality, the causes of the high voltages that arise in static electrification all stem from the relationship:

$$V = Q/C$$

where V is the voltage between a charged object and earth, (or indeed between any pair of dissimilarly charged objects), Q is the charge in coulombs, and C is the capacitance in farads. Since the capacitances between charged objects and their surroundings may be very small, even a small charge can sometimes give rise to a very high electrical potential.

Contact electrification

Although there are many mechanisms by which these charges can arise, undoubtedly the most common is that of contact electrification, and the major mechanism by which this happens is that of transfer of electrons from one of the contacting surfaces to the other.

All materials contain electrons, although only in conductors or semiconductors is free movement normally possible. The migration of electrons between contacting bodies is a concept which is familiar in the context of normal conductors, where electron mobility is high, and electron flow can be defined in relation to the Fermi levels of the contacting materials.

However, even in non-conducting materials, when two dissimilar surfaces are brought into contact, the differences in the contact potential between them can still cause a limited flow of electrons between one and the other - even though the regions involved may be confined to the depth of a few molecular radii on either side of the contacting surfaces.

In the case of insulators, this charge transfer is possible because molecular deformations or surface contaminants will always be present, and will produce some mobile surface electrons. Even superficially identical surfaces may still differ enough, on a microscopic scale - through minor local differences in chemistry, physical state or history - for charge transfer to occur.

This is normally referred to, rather loosely, as "charge separation", and is promoted by friction, pressure and heat.

While it is true that physical contact is not always essential, even in air at normal atmospheric pressure, for the migration of electrons, it is probable that the actual potential differences between contacting surfaces will not be high enough to cause ionisation, so the bulk of charge transfer will occur where actual surface to surface contact takes place.

However, on a microscopic scale, all surfaces will probably be very irregular, and may look something like my sketch of figure 1, where the actual contact area will be very small, and the opportunities for charge transfer consequently relatively slight. If the two surfaces are moved relatively to one another while being held in contact (friction), the peaks on each surface will sweep across the other, increasing a point contact to a line contact.

Further, if the pressure between the surfaces is increased, the contact areas will increase as the points flatten out, as I have sketched in figure 2. If the surface temperature rises, perhaps simply as a result of frictional heating, the local electron mobility will increase and the rate of transfer of charge will be greater. Also, in some materials, plastic deformation may cause a greater area of contact.

If the two surfaces are separated, after electrons have migrated from one to another, an increasing electrostatic potential will arise as the capacitance between the two surfaces decreases. In good

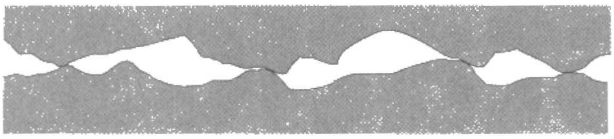


Figure 1: typical nature of contact between surfaces

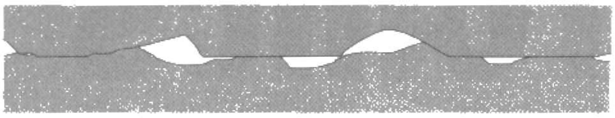


Figure 2: increased surface contact due to pressure

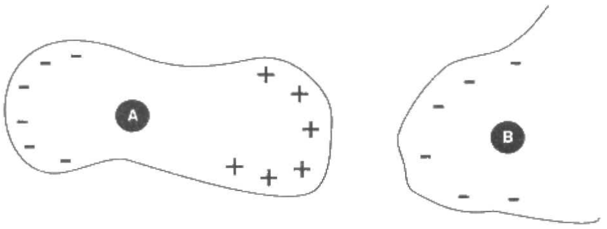


Figure 3: mechanism of charging by induction

conductors, the electrons will simply flow back across the last remaining contacting bridge as the surfaces come apart and the residual asymmetry in charge distribution will be very small.

However, in insulators, this possibility of current flow across the surface is very much less, and quite high voltages will occur as the two faces are separated, especially if their areas of contact have previously been high, and their surface potentials are very different. This effect can be seen when one peels off a strip of black PVC insulating tape in a dark room, when a line of bright sparks can be seen at the place where the strip peels away.

The longevity of such electrostatically induced voltages is influenced both by the length of the path by which the charges may leak away, and by the degree of conductivity of the materials. Because of this, the effect of increasing surface temperature in promoting electrification will be limited, in the end, by the resulting increase in conductivity of most insulating materials as their temperature is increased.

The contact between an insulator and a metallic conducting surface provides a particularly effective opportunity for electronic charge transfer, and this is a particular source of problems for the manufacturers and users of thin plastics films, especially if some form of rubber "nip" roller is used to force the film into contact with the roller in order to pull it through some machine.

This situation is, or was, prone to give rise to some quite astonishing degrees of electrification. Nowadays, most plastics packaging films are fairly heavily larded with anti-static agents to make their surfaces conductive, so this problem is less acute, except where, as in capacitors, the films are still made from virgin polymers.

Induced charges

Induced charge is the second major mechanism by which electrification occurs, and which is seen in its most spectacular manifestation in thunder storms. If object A, as in figure 3, is brought into proximity to a negatively charged object B, electrons or negatively charged ions will be repelled away from object B, leaving A with an asymmetrical charge distribution.

Now, if A is a water droplet within a cumulo-nimbus cloud, and B is the strongly negatively charged base of the cloud, and if A is fragmented (torn apart) by the strong updraught of air within the cloud, it is possible that the portion bearing the positive charge will be swept up by thousands of feet, causing the lower part of the cloud to become progressively more negatively charged, and the top or "anvil" of the thundercloud progressively more positively charged. Measurements suggest that the potential differences in such cloud formations can lie in the range between 100 million and 1000 million volts.

The cloudbase lies a few thousand feet above the earth's surface - often less - while the cloud tops often exceed 30,000 feet in altitude. Since the base of the cloud is therefore often closer to the surface of the earth than it is to its own top, flashover will normally occur to the earth. Measurements on these flashovers suggest currents peaking as high as 200,000 amperes, though levels around 50-500 A seem to be more common. These discharges tend to be oscillatory, and may be prolonged to a duration of 0.5 second, in some cases, at decreasing current levels.

The speed of the downward strike in which such lightning strikes are normally initiated (except in the case of very tall buildings where a 'ground leader' may occur) is relatively slow, at some 50 metres per microsecond, though the velocity of the highly visible return flash, up the strongly ionised core of the discharge path, may reach a third of the velocity of light.

Both Wimshurst machines and Van der Graf generators rely on a combination of induced charges on a moving carrier and the reduction of the capacity between the charged element and its surroundings to produce high output voltages.

Common examples of charge generation by such mechanisms include those of dust carried about by air currents in flour mills and similar places; steam escaping from the funnels of rubber-tyred traction engines (for which a trailing earthing chain is essential, if only to allow small boys to hook it up out of contact with the ground, to the subsequent surprise of the driver); and in the handling of electrically non-conducting liquids such as oils or petrol, in which charges arise when they are poured from one container to another. Dangerous explosions occur all too frequently in these circumstances, when a spark discharge ignites the mixture of air and the inflammable vapour, and this has sometimes resulted in the destruction of oil tankers through explosions in their oil tanks, even when engaged on the apparently innocuous action of washing out the empty tanks with water.

Charging by mobile ions

This mechanism is not often found in the context of inadvertent electrification, but it can arise if previously uncharged objects pass close to conductors carrying high electrical potentials, especially if these have sharp edges or corners.

This is because the electrostatic stress which arises on the surface of a conductor is proportional to the voltage and inversely proportional to the radius of curvature of the surface. If a voltage is applied to a conductor which terminates at a sharp point, the gas surrounding it may ionise if the electrical stress in the vicinity of the point exceeds the ionisation potential of the gas. Because the ions generated at the point will be predominantly of the same polarity as the conductor, they will be repelled away from the point in the form of an ionic wind, and can charge any conducting surface by which they are captured.

This mechanism is employed deliberately, both to charge surfaces, as in Wimshurst and Van der Graf machines, and also to discharge them, as in a range of commercially available static eliminators.

These contrivances are built, most commonly, in one or other of the forms shown in figure 4. In 4a, two parallel rows of spikes, attached to a conducting bar, and mounted on either side of a central separating plate of some non-conducting material, are connected, respectively, to positive and negative voltage supplies, typically of the order of 15kV, so that each electrode will generate an oppositely charged stream of ions. The use of such high source voltages is necessitated by the consideration that corrosion, and the accumulation of conductive debris on the points of the electrodes, will rapidly reduce their effective radius of curvature to a less useful value. In the simpler form shown in figure 4b, only a single row of spikes is used, mounted, as before, on a common connecting bar, which is insulated from its earthed protective outer case. This is fed from a high voltage AC source - typically in the range 7-10kV - in the expectation that the ions so generated will have moved sufficiently far away from the points of the electrode that they will not be neutralised immediately by the oppositely charged ions generated when the supply voltage swings to an opposite potential.

In both cases, it is hoped that a mixed stream of positively and negatively charged ions will be propelled toward the surface whose electrostatic potential the user wants to discharge. Since the high voltages would provide a hazard to operators, the power supplies are arranged to have a very high output resistance, to restrict the maximum output current flow to much less than one milliamp.

Component problems

Since their inception in the 1960s, a whole array of electrostatic charge operated devices has emerged, originally classed as Insulated gate FETs, but now almost always described as "-MOS" (metal oxide silicon) devices, in one version or another, usually referring to their method of construction, such as T-MOS, D-MOS, N-MOS, P-MOS or C-MOS, which is misleading since the gate conductor is, to an increasing extent, made from polycrystalline silicon in the interests of device operating speed.

The current flow in these transistors occurs because of the creation, by electrostatic induction, of a layer of mobile charge in an otherwise non-conducting region of semiconductor material, as shown in figure 5 in the cross-sectional drawing of a simple lateral mosfet.

Since it is very desirable that the induced charge should be as large as possible for the lowest practicable gate voltage as determined by the equation:

$$\theta = Q/4\pi e0R^2$$

where θ is the induced electrostatic potential, e0 is the charge on the electron, and R is the thickness of the insulating layer, (in this case between the buried gate electrode and the "P-" layer beneath it), every effort is made in manufacture to ensure that R is very small - so long as it is capable of withstanding the normal range of operating voltages, without too great a risk of electrical breakdown of the gate insulating layer which would make the device non-functional.

Such -MOS devices will normally induce an adequate layer of charges (electrons in the model illustrated) for a useful current flow when only some 2-3V is applied to the gate. The breakdown of the dielectric layer may then occur above an applied potential in the range 10-40V.

Since the breakdown voltage of this layer is a crucial factor in the reliability of the component, care must be taken to mitigate the increase in the electrical stress at the edges of the gate electrode, which is an important phenomenon even at these voltages.

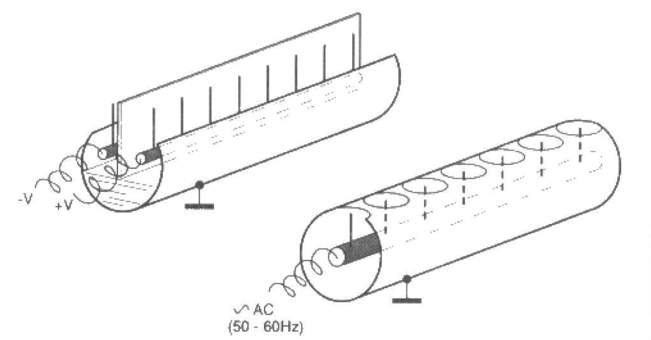


Figure 4: construction of typical static eliminators

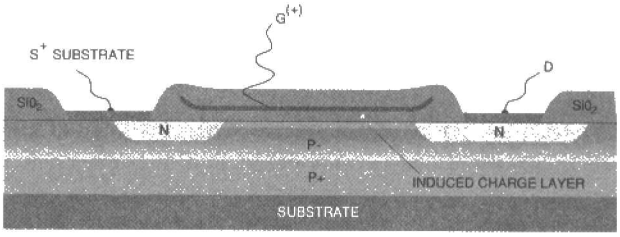


Figure 5: schematic construction of N-channel enhancement mosfet

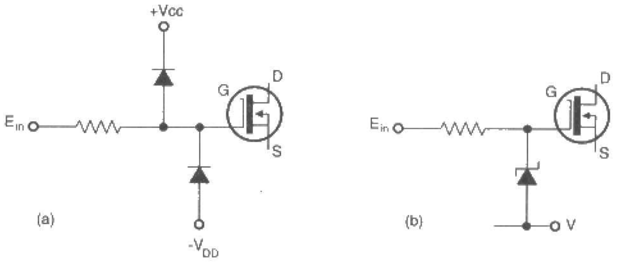


Figure 6: diode protection of small signal/logic mosfets

The shape of the "well" in the oxide layer within which the gate conductor is deposited must therefore be chosen to simulate a radiused edge to this electrode. Similarly, the bottom of the gate "notch" in VMOS devices must be rounded or flattened to limit the electrical stress which will occur at this point.

The proneness of -MOS devices to accidental gate-source breakdown during handling, when perhaps the gate lead is touched by a charged object (such as a constructor, for instance), while the source (or drain) connections are at earth potential, depends on the voltage which the applied charge will produce.

As shown in equation 1, this will depend on the gate source capacitance, which will be very much less in a small signal device, or a logic gate, where the input capacitances are only of the order of a few tens of pF, than in the case of a power mosfet, in which the gate-source capacitance may be as much as 2-3nF.

Fortunately, in the case of small-signal devices such as transistors or logic gates, it is practicable to form gate protection diodes on the chip, either as simple diodes to hold the gate voltage within 0.6V of the supply line potential, as shown in figure 6a, or as zener diodes, to set a permissible voltage excursion on either side of some reference level, as shown in figure 6b.

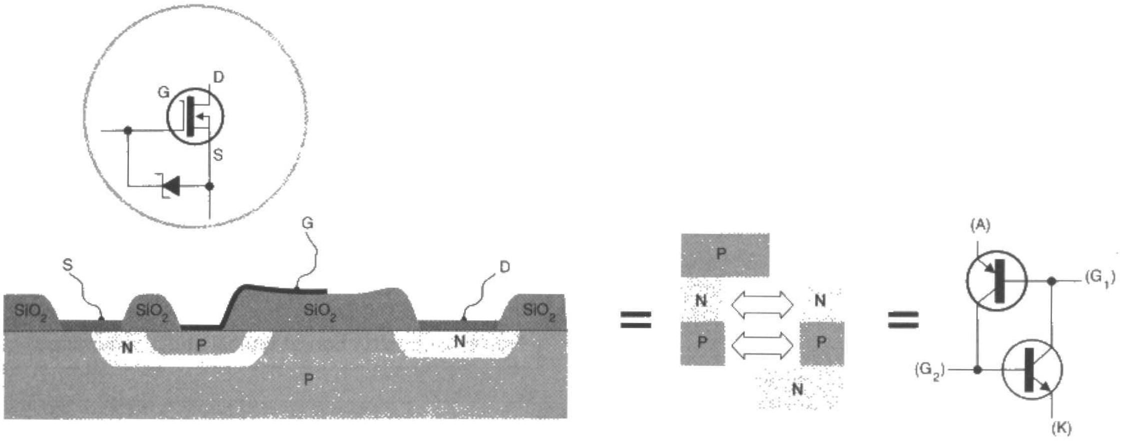


Figure 7: diffusion structure for protective diode on-chip

Protection in installation and use

Diode or zener protection is not practicable in power devices, because an on-chip fabrication of the protective diode will allow a thyristor-type configuration of the junctions, as shown in figure 7, and this could cause the device to trip into a permanently conducting state. However, because of the large gate capacitances involved, it is relatively difficult to damage power mosfets by externally applied electrostatic potentials inadvertently generated by the movement or clothing of the operator.

This does not mean that it is impossible to envisage situations, such as a laboratory or factory where there is very low atmospheric humidity, and where the worker wears clothing made from some high quality plastics insulating material, and sits on insulated metal seated chairs, standing on a well insulated floor, on which he walks on shoes with insulating soles, in which a quite destructive electrostatic charge could arise.

It is to be hoped, however, that the continuous electric shocks which the worker in such an environment would receive, whenever he or she touched some earthed conductor, would have persuaded the management that something needed to be done before work begins connecting MOS devices.

Some elaborate precautions have been recommended, and adopted, to make sure that MOS devices are protected against inadvertent damage during handling, but in the kind of climate with which north-western Europe is blessed, the use of leather soled shoes, and cotton or woollen clothing, seems likely to avoid most hazards due to the movements of the constructor handling the devices.

I feel myself that static has been given an unnecessarily bad reputation as a source of failures in MOS devices, since, in my own experience, having handled thousands of these components in one form or another, and worked in labs where many others were engaged in similar tasks, immediate failures were very rare indeed.

Indeed, the only instances where component failure could confidently be blamed on excess potentials applied to the gate of the device during installation were those in which non-gate-protected small signal devices were soldered in place by a worker who had disconnected the earth connecting wire from his mains voltage operated soldering iron, at the plug, for reasons which seemed good to him at the time. Unfortunately, this had the effect of causing the bit of his soldering iron to sit at about 170V peak with respect to any other earthed object, such as, perhaps, the unlucky transistor!

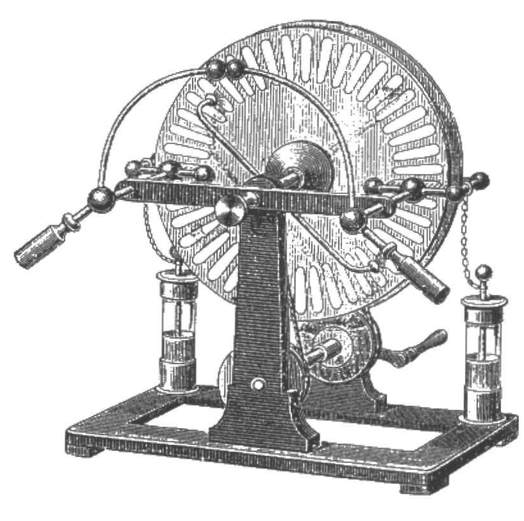


Figure 8: a Wimshurst electrical machine

It is not however unreasonable to take the view of many engineering managers, especially those working on small or specialised production lines, that the effort and expense needed to discourage even the rarer causes of possible failure is generally less than the effort and expense required to recall, test and repair or replace a failed unit. Weakening by static damage has been blamed for some failures "down the line" after the unit has left the workshop. So basic precautions, especially on those dry days that sometimes occur even in the United Kingdom, when every doorhandle behaves like a spark-generator, are best not forgotten - particularly if your employer or manager requires their observation.

However, most failures attributed to static, seem, on examination, to be due to incorrect use, excessive circuit voltage or, in the case of very high frequency power transistors, by badly chosen layout or circuit configurations which have allowed runaway HF oscillation.

Admittedly, factory assembly procedures will give rise to other problems, but these are principally within the province of the engineers who design the machines used for automatic assembly, and where an understanding of how electrification occurs, should allow the design of processes which are reasonably free from static charge generation.

PIC DRIVEN

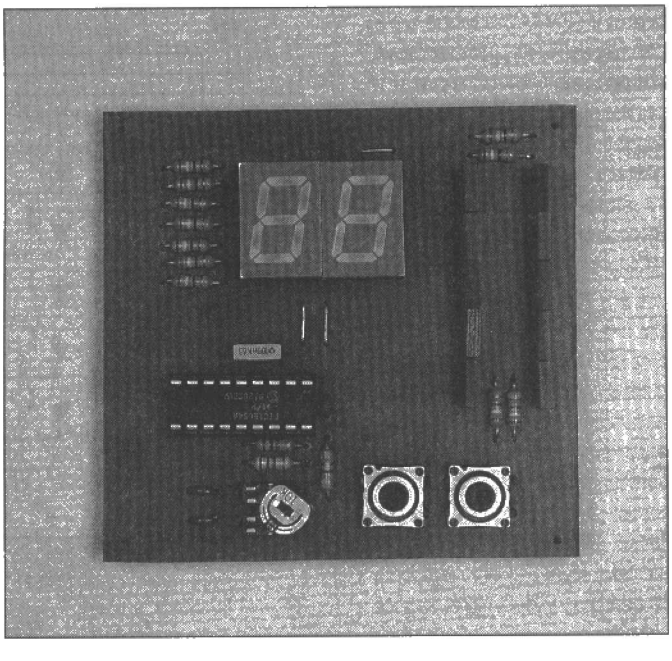
IQ Tester

If you have the sense you were born with, argues Bart Trepak, this scientific reaction tester should tell you whether you have the intelligence too.

It has been said that intelligence is that which enables people to get along without an education, while an education enables them to get along without intelligence. Be that as it may, psychologists and educators have long debated the nature of intelligence - whether it is something one is born with or acquires and, more particularly, how can it be measured.

The Greek philosophers were the first people to consider this problem and Plato theorised that men were set apart from other animals by the possession of what he called "the soul". This, he said, was divided into three parts: appetite - such as hunger, thirst and so on; reason - deciding, for example, not to eat poisoned food even though one might be hungry; and the spirit - embracing such ideas as honour, propriety etc. The proportion of these in an individual determined how intelligent he was. He maintained that the proportion was determined by birth, and since the upper classes were better endowed with the more noble portions than were the slaves, for example, it was only natural that they should rule. Since it was "obvious" which people possessed intelligence by virtue of their parentage, the question of testing conveniently did not arise.

For the next few centuries, most people busied themselves with finding something to eat while the more intelligent fought and squabbled to determine who was more "intelligent" and should therefore rule and so not much more was done in this field until the end of the 19th century when some people began to acknowledge that there were intelligent people among the "lower classes" of society and began to look to physical attributes such as strength, speed, colour of eyes, race and even the number of protuberances on the head to see if any of these were a pointer to above average intelligence. These theories were found to be flawed, but it was noted that people who were good at a task which required, say, memory, could also be expected to do well at another which involved, for example, copying complex patterns. This led psychologists to try to devise tests for determining intelligence on a more scientific basis.



A person's intelligence is not simply of academic interest, however. It can also be important to an employer who wants to know that the prospective employee at an interview will be up to the job for which he or she has applied. Examination results and qualifications may be a guide to past performance, but will the candidate be able to adapt to changing methods or technology as these come along and contribute something new to the position? Unfortunately, depending on how the examination questions are selected and marked, these may prove that a student has a good memory (but not necessarily that he or she understands subject), or that he had a bad cold on the day and was not at his best, or even that there are too many people passing in a given subject and it is time to limit the numbers... but will not guarantee that the individual will be good at a job. Indeed, poor examination results and lack of qualifications do not necessarily mean that a person will be unsuitable for a job - Einstein and Churchill were both failures at school. Similarly, a good degree in a particular subject will not guarantee that a person will be good at a particular job.

Because of these inconsistencies, on many courses students are now also assessed continuously. This is still far from perfect and not only takes much longer to determine, but also suffers from being mainly "knowledge based".

To try and get around this "knowledge based" selection, IQ tests were devised and first used by the US Army in the First World War when they wanted to decide who was going to give the orders to dig trenches and who was going to dig. At this time, there was a sudden need for large numbers of officers who would have to be recruited from people who had had no experience of, or qualifications for, a job in the army and there was obviously no time to send everyone on a course to see if they could pass an exam. (Interestingly, the British Army, and to a certain extent the German and French Armies in this period seem to have adhered to Plato's view of intelligence to select their officers. History has documented the results). For similar reasons, more and more companies and colleges are giving IQ tests to prospective students and employees in an effort to select the most suitable candidates.

Knowledge vs. concentration

Nowadays, IQ tests usually consist of reasoning tasks presented in mathematical, verbal, visual and other formats to reflect the spread of special mental abilities. Many different tests have been devised but all of them tend to confuse knowledge with intelligence to a greater or lesser degree. A test set in English would obviously place someone with poor English at a severe disadvantage, while a question such as "Select the odd one out : Wilson, Macmillan, Constable, Eden and Heath" could be difficult for say a person of Chinese origin who may not be familiar with British Prime Ministers and painters but could easily answer the question if the list had consisted of Chinese leaders and artists.

Today's tests are therefore carefully designed to test a subject's ability, while avoiding as much as possible knowledge/culture-specific problems. They are, however, still time-consuming to perform and mark and do not overcome all the difficulties. But help may be on the way.

Regular viewers of "Tomorrow's World" may remember, some time ago, a report on American research into the measurement of intelligence. A researcher noted that the work had shown a strong correlation between a person's ability to concentrate on a given task and their intelligence as measured by an IQ test. He then proceeded to demonstrate a PC programme which could provide the "task" to test the subject's intelligence.

The program was quite simple, and showed two vertical lines on the monitor screen, one of which was slightly longer than the other. After a fraction of a second, the program made both lines the same length and the user was invited to press one of two keys on the keyboard to select which of the lines had been longer. After a suitably large number of attempts, a final score depending on the number of correct answers, was displayed on the screen. This, it was claimed, gave a measure of the subject's intelligence.

PIC your brain

Always on the lookout for good project ideas, I immediately saw this sledge hammer solution as a perfect candidate for pressing into use some LEDs and counter ics. When I began to think about it more seriously, I soon realised that I would need about seven or eight cmos or ttl chips to drive the LEDs and do the counting and decoding, and the thought of all that wiring and soldering made me decide that it was far more intelligent to use a computer after all - not the kind with a colour monitor and 2 gigabytes of hard disk storage, but a single chip micro-controller. This could easily be programmed to control two strings of LEDs to make up the two lines and keep the score on a seven segment LED display, and two push button switches would replace the keyboard.

I decided to base the circuit on a PIC16C54 cmos microcontroller which contains all the basic parts of a computer (alu, ram, power-on reset circuit, built-in clock generator etc.) including eprom program memory and 12 input/output lines which can drive LEDs direct, making it ideal for this application. The circuit diagram is shown in figure 1 and is quite straightforward. Apart from the chip, only the switches, LEDs and displays are required, together with a handful of current-limiting resistors and two capacitors. All the work is done by the micro-controller, which switches on each digit in turn while at the same time driving the display segments and LEDs and checking the status of the switches. (A pre-programmed micro-controller is available from the author.)

VR1, R1 and C1 form the clock oscillator circuit and control the speed with which the instructions are executed and the length of time for which the two LED columns are displayed. By varying VR1 therefore, the test may be made more or less difficult.

The circuit draws about 40-50mA (at 5 volts) depending on the score that is being displayed and can be powered from any supply in the range 3 to 5V. It is, therefore, possible to use two AA cells in series, although better performance would be achieved with the larger capacity C cells. In view of the rather large current consumption due to the LEDs, it is perhaps better to use rechargeable batteries. As nicad rechargeable batteries have a voltage of 1.2V as opposed to 1.5V for non-rechargeable types, two nicad cells would provide only 2.4V, which would not be sufficient. It is, therefore, prudent to fit a 3 x AA or C battery holder which would allow operation with either type of battery.

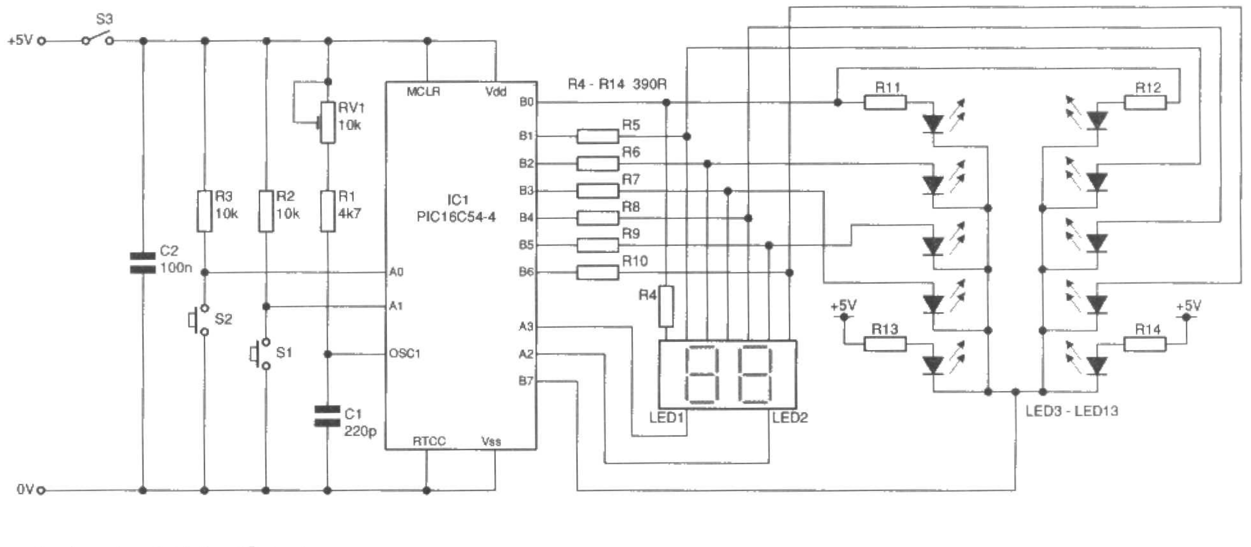


Figure 1: the circuit of the IQ tester

Alternatively, a mains supply of the type used to power small appliances could be used. A stabilised type is preferable but if you wish to build your own, a suitable circuit is given for mains constructors in figure 2.

Construction

Although the circuit could be built on a piece of stripboard, a far neater assembly can be realised using a printed circuit board (see figure 3 for the component layout). All the components with the exception of the two push-button switches and the on/off switch are mounted on the PCB, along with the links which can be made from discarded component leads. Construction should begin with the lowest profile components first, namely the resistors and links followed by the LEDs and capacitors. Note that the board has been designed so that all the LEDs are mounted with their cathodes towards the bottom edge of the board. All the components can be soldered directly to the PCB but an 18-pin socket is recommended for IC1, which is a cmos device and all the normal precautions should be taken when handling this ic.

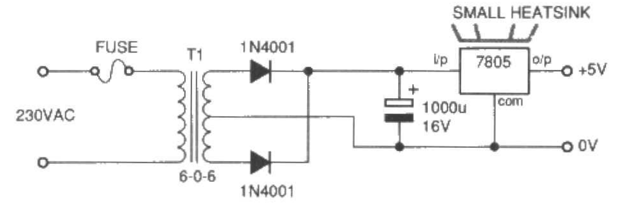


Figure 2: a suitable power supply circuit for mains constructors

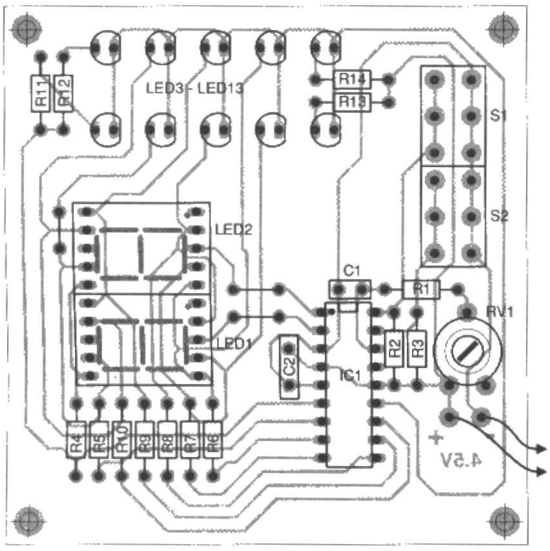


Figure 3: the component layout for the PCB

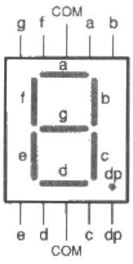


Figure 4: the display pin-outs

No details are given on mounting the unit in a box as this will depend on personal preference. Any plastic box large enough to house the circuit together with the batteries or mains supply will be suitable, provided there is sufficient space on the front panel to mount the printed circuit board (or at least the LEDs and displays), two pushbutton switches and an on/off switch. Ideally the pushbuttons should be mounted below the two LED columns so that there is no confusion about which switch corresponds to which column. A sloping front case would perhaps be most appropriate and provide maximum flexibility in the positioning of the displays and switches. If required, the display and LEDs could, of course, be mounted off the PCB but this would involve a lot more wiring and the possibility of errors. The connections for the LED display used are shown in figure 4 should this need to be done or if a different display is to be used. VR1 could also be replaced by a panel mounted component to allow the difficulty of the test to be varied, although it is probably better to leave this control out of sight of the subject.

The LEDs used in the prototype were rectangular types which are slightly more expensive than the normal round types, but provide a better display with no "gaps" as would be the case with round types or the so-called bar graph arrays. Arrays do have the advantage of being easier to fit into a straight line and they are available in strips of 5. Brightness matching is also a problem which is not encountered with arrays, so if you are using discrete LEDs it is best to buy them all from one source or you may have to spend some time adjusting resistor values to get an even brightness along the whole column.

The flowchart

Figure 5 shows the flowchart which explains how the program works and is probably more important than the circuit diagram in understanding it. When the circuit is first switched on, the program goes through a routine which defines which lines will be inputs (A0 and A1) and which outputs, and initialises all the registers. The score counter is set to zero and another register which keeps track of the number of tries is set to 99 (decimal). The input A0 is then read and if it is low (ie the switch is kept depressed when the unit is switched on), the lines A2 and A3 are defined as outputs enabling the score counter displays to light. (Note that at power on when the score is zero, the leading digit is suppressed so don't worry when it does not light.) If the switch connected to input A0 is not depressed, these two lines are defined as inputs, and since they are used to drive the digits, the score display is effectively blanked. This can be useful because it not only reduces current consumption but the display can be distracting. It is quite easy to keep watching the display to see if the correct button was pressed and if the score increased, and miss the next column display and not know which button to press next although this may add to the validity of the test by checking that the subject can concentrate despite distractions. Both these modes of operation are therefore available and may be selected by either keeping the switch S1 depressed when the unit is switched on, or not doing so.

Following the power-up procedure, the program now scans the display, switching on (or at least attempting to) each display in turn and then the LEDs as well as selecting which LED column to make longer and checking to see if the switch connected to A1 has been

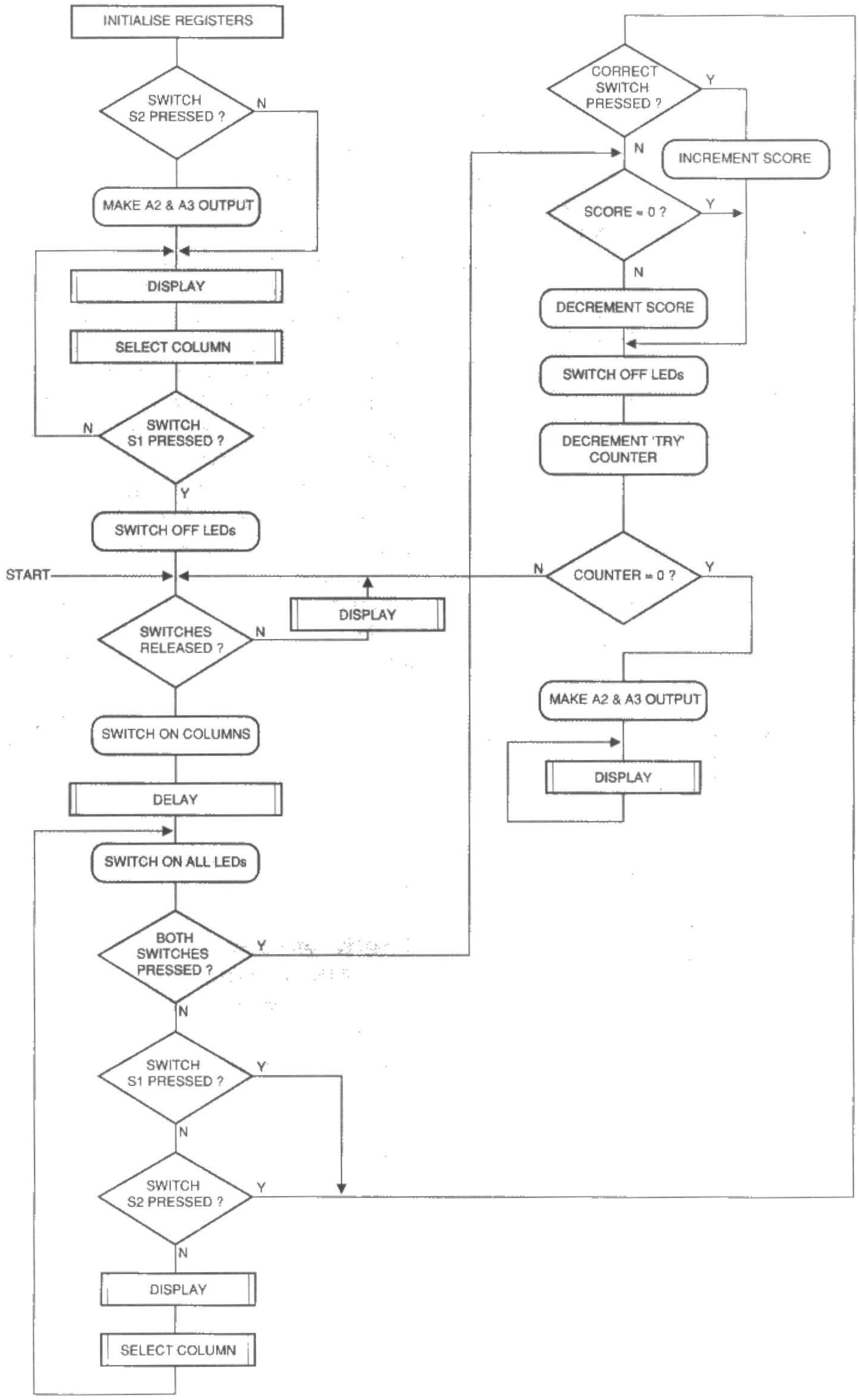


Figure 5: the flowchart for the IQ tester software

depressed. If it has not, the program remains in this loop constantly switching between the columns. Since this happens many hundreds of times a second, it is impossible to know which column will be chosen so that the final selection is to all intents and purposes random.

When the switch connected to line A1 is depressed, the LEDs are switched off and when it is released they are switched on again with one column longer than the other. This is the start of the program proper and is marked as such on the flowchart. After a short delay (determined by a subroutine and the clock frequency) all the LEDs are lit and the program waits for a pushbutton to be pressed. While it is waiting, the program continues displaying the score (assuming A2 and A3 are outputs) and selecting a column. When the pushbutton associated with the longer column is pressed (A0 corresponds to the left-hand column), the score counter is incremented and the counter recording the number of tries is decremented, while if the other button is pressed only the "try" counter is decremented.

For the more intelligent subjects who may think that they can achieve a higher score by pressing both buttons simultaneously, and actually manage to do this, the program is written to accept this as an incorrect answer and simply decrement the "try" counter.

When the pushbutton is released, the program checks to see if the "try" counter has reached zero, indicating the end of the test. If it has, the lines A2 and A3 are made outputs (if they were not in this state already) and the program goes into a loop continuously displaying the final score until it is switched off. If the "try" counter is not zero, the program goes back to the start and displays another set of columns for another try.

Initially the program was written as above, but there was one difficulty. It is well known that if you spin a coin enough times and call heads, on average you will be correct 50% of the time. The same is true of this tester, as there are only two pushbuttons to choose from and each time one of them must be correct and the other wrong. This means that even a chimpanzee which could not understand the rules, or continuously pressed one button, would achieve a score of about 50. To overcome this difficulty, each incorrect answer is made to decrement the score so that our chimp with a supposed low IQ, pressing the same button all the time, would get on average a score of zero or at least a low value, because on average there would be as many incorrect answers as correct ones. To prevent a negative score, which would not only be insulting presumably even to a chimp, but also a concept which would be difficult to visualise (not having the sense one was born with, perhaps), any score less than zero is rounded up to zero.

The LED columns are organised so that the bottom LED in each column always lights. The column which has been selected to be longer is made either one, two or three LEDs longer than the short one, giving eight different possibilities. This has been done because otherwise the eye will tend to get used to where the split between the long and the short column occurs if one column is always made, say, one LED longer than the other, and focus only on the two LEDs involved. The other LEDs would not be observed and , in fact, would not even need to be fitted. The whole point of using columns instead of just two LEDs is to make the test harder and force the subject to concentrate more which he will have to do because he will never be sure how much longer one column will be with respect to the other.

Does it work?

IQ is measured by psychologists on a scale from 60 to 140 with a score less than about 80 representing the very dull, and over 120 being very bright as shown in figure 6. According to this, half the population have an average intelligence which is represented by a score of between about 90 and 110, with a decreasing number of people as we move into the very bright and the very dull areas. Only some 2 percent belong to the MENSA level of very bright with a score of 130-plus. Interestingly, women tend to cluster around the average with fewer at the bottom or top. The peak intelligence of an individual is said to occur at around the age of twenty three (so I still have some way to go) but then gradually fades - so older may mean wiser, but not necessarily more intelligent. Another thing to remember is that an IQ number is simply a score and has no quantitative value. Thus a person with an IQ of 120 cannot be said to be twice as intelligent as one with a score of 60 and, in fact, the difference is said to be quite small.

Concerning the validity of this particular test, I suppose one could argue that any person who can concentrate on a task, even one as pointless and mundane as deciding which of two columns of lights was longer, would stand a good change of concentrating on learning a skill or job and, therefore, become proficient at it faster than a person whose mind tended to wander off the subject. Whether this is "intelligence" or not is debatable, but the test certainly requires concentration, especially at the higher speeds, so if nothing else, it could be used to select people who could learn a new job easily from those who could take longer. To test this properly, one would need to have subjects with known IQs and compare their score with their IQ rating. For this reason it is also difficult to translate the score of 0-99 into the generally accepted one of 60-140 normally used to grade IQ but again, it should provide a guide. This could be a good project for a school class where the results of such a test on the pupils could be compared to their examination results or indeed IQ scores if these are known.

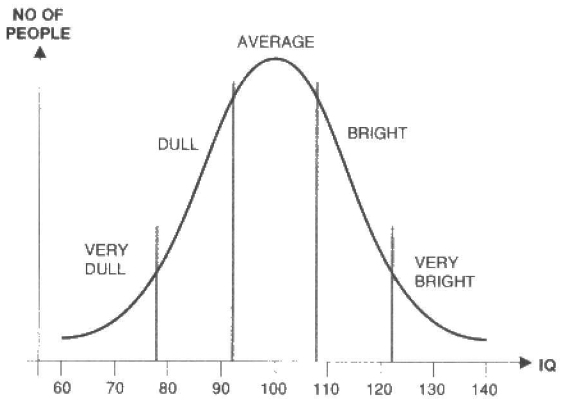


Figure 6: conventional IQ distribution in the population

Having played with the device, I must say that I was most impressed with its accuracy and although modesty prevents me from revealing my score, I am prepared to divulge that it was in double figures - at least on the slower speeds. Suffice it to say that based on this, I will now seriously consider whether or not to decide about the possibility of thinking about sending off my application to MENSA, but perhaps I should build a microprocessor controlled decision maker first. But don't take my word for it, try it - its very simply to build and as addictive as some computer games (and probably a good deal less boring than some) and who knows, the next job you apply for may well include just such a test at the interview!

PARTS LIST

Resistors

R1	4k7
R2, R3	10k
R4-R14	390R (11off)

Capacitors

C1	220pF ceramic
C2	100nF ceramic
IC1	PIC16C54-4 (pre-programmed) (Order as PIC16C54-4G)
VR1	10k Preset

Miscellaneous

LED1,LED2	CC LED display
LED3-LED13	Rectangular red LEDs or two 5-LED bar graph arrays.

PCB, 2 x push to make switches; ON/OFF switch, battery holders, box.

The Pre-programmed PIC micro-controller is available from the author for £9.50 including UK carriage. (Overseas orders please add £2.) Please send Postal orders/cheques/bankers draft in £ sterling together with your name and address stating clearly which project you are building, to:

B. Trepak, 20 The Avenue, London W13
8PH. (Mail order only)

```
;*******************************************
;           IQ TESTER
;*******************************************
;This program lights two columns of
LEDs briefly, one longer than the other.
The user has to press a push button
corresponding to the longer column. The
try counter (TRYCTR) is decremented
from 99 and if the correct button was
chosen, the score counter (SCRCTR) is
incremented. After 99 tries,(TRYCTR=0)
the score is displayed. If switch A0 is
depressed during the power up
sequence, the score will be displayed
continuously.
;*******************************************


FLAG equ 07h  ; Flag register
BCCTR equ 08h ; determines if B1/B5
    or B2/B6 will be high
BCREG equ 09h ; used to display LED
    column using data from BCCTR
TRYCTR equ 0Ah ; TRY CounTeR binary
    loaded with 99 dec
SCRCTR equ 0Bh ; SCoRe CounTeR -
    counts up in BCD 2 digits
DLY equ 0Ch ; DeLaY counter
LEDREG equ 0Dh ; LED REGister stores
    which LEDs are to be displayed
    ; when DSCR is called
DSPLY equ 0Eh ; holds display
NREG equ 0Fh ; holds number N which
    controls how long columns display
NCTR equ 10h ; counts from N to zero
LEDCTR equ 11h ; counts 8 to
    determine which leds will
    light##########
COLUMN equ 12h ; stores LEDCTR
    contents when leds
    selected############

    LIST P=16C54;f=inhx16

INCLUDE "PIC.H"
;*******************************************
    goto START
;
;*********INITIALISE SUBROUTINE*********
INTLSE  movlw 03h
    tris PORTA
    movlw 00h
;   movwf PORTA
    tris PORTB
    movwf PORTB
    movlw 0FFh
    movwf PORTA
    movwf FLAG
    btfsc PORTA,0
    goto INT1
    clrf FLAG
;
INT1    clrf SCRCTR
    movlw .99
    movwf TRYCTR
    clrf BCREG
    movlw 42h
    movwf BCCTR
    movlw 07h
    movwf LEDCTR

;
;*******************************************
;
;*****DISPLAY SCORE SUBROUTINE****
DSCR    movf SCRCTR,w
    movwf DSPLY
    andlw 0Fh
    call CONVRT
    movwf PORTB
    movf FLAG,same
    btfss STATUS,2
    goto DSCR2
    movlw 0Bh
    movwf PORTA

DSCR2   call DELAY
    movlw 0FFh
    movwf PORTA
    swapf DSPLY,w
    andlw 0Fh
    btfsc STATUS,2      ; leading zero
                        blanking
    goto DSCR1          ; if leading
                        digit is zero
    call CONVRT
movwf PORTB
    movf FLAG,same
    btfss STATUS,2
    goto DSCR3
    movlw 07h
    movwf PORTA

DSCR3   call DELAY
    movlw 0FFh
    movwf PORTA     ; Switch off display
DSCR1   movf LEDREG,w
    movwf PORTB     ; Display LEDs
    call DELAY
    retlw 00
;
;*******************************************
;
CONVRT  addwf PC,same  ; add BCD
                          offset to PC
    retlw 0FEh      ; 0
    retlw 0B0h      ; 1
    retlw 0EDh      ; 2
    retlw 0F9h      ; 3
    retlw 0B3h      ; 4
    retlw 0DBh      ; 5
    retlw 0DFh      ; 6
    retlw 0F0h      ; 7
    retlw 0FFh      ; 8
    retlw 0FBh      ; 9
;
;*******************************************
;
LEDCVT  addwf PC,same   ; determines
                          LED pattern
    retlw 08h       ; 0000 1000
    retlw 04h       ; 0000 0100
    retlw 18h       ; 0001 1000
    retlw 24h       ; 0010 0100
    retlw 1Ch       ; 0001 1100
    retlw 2Ch       ; 0010 1100
    retlw 3Eh       ; 0011 1110
    retlw 7Ch       ; 0111 1100
;
;*******************************************
;
; ********DISPLAY B/C SUBROUTINE*****
DBC     ;movf BCCTR,w
    ;movwf BCREG
    ;iorlw 98h
    ;movwf LEDREG
    movf LEDCTR,w
    movwf COLUMN
    call LEDCVT
    movwf LEDREG
    retlw 00
;
;*******************************************
;
; ***********DELAY SUBROUTINE*********
DELAY   movlw .100
    movwf DLY
D1 decfsz DLY,same
    goto D1         ; if not zero
    retlw 00        ; if zero end of delay
;
;*******************************************
;
; **INCREMENT SCORE SUBROUTINE**
INCSCR  incf SCRCTR,same
    movlw 0Fh
    andwf SCRCTR,w
    xorlw 0Ah
    btfss STATUS,2
    retlw 00
    movlw 06h       ; low order digit[right
                    arrow]10 - add 6
    addwf SCRCTR,same
    retlw 00
;
;*******************************************
;
CMPBC   decfsz LEDCTR
    retlw 00
    movlw 07h
    movwf LEDCTR
    retlw 00
;
;*******************************************
;
START   call INTLSE ; initialise option,
                    regs, timers etc.
    movlw .20
    movwf NREG
;
BEGIN   movlw 7Fh   ; ie 0111 1111
    movwf LEDREG    ; switch on all LEDs
    movwf NCTR
    call DSCR
    call CMPBC
    call DELAY
    btfsc PORTA,1       ; test if A1 pressed
                        ie =0
    goto BEGIN          ; not pressed
AX      movlw 80h       ; ie 1000 0000
    movwf LEDREG        ; switch off all LEDs
    call DSCR
    btfss PORTA,1       ; test if A1
                        released ie =1
    goto AX             ; still pressed
GX      call DBC        ; A1 released -
                        start test
    decfsz NCTR         ; delay before start
                        of test
    goto GX
    movf NREG,w         ; TEST STARTS
                        HERE
    movwf NCTR          ; load NCTR from
                        NREG (controls
                        display
        ; time of LED columns
BX      call DSCR
    decfsz NCTR
    goto BX             ; if NCTR is not zero
    movlw 07Fh          ; ie 0111 1111
    movwf LEDREG        ; switch on all LEDs
EX      call CMPBC
    call DSCR
    movf PORTA,w
    xorlw 00h           ; test if both
                        switches pressed
    btfsc STATUS,2
    goto CHEAT          ; if zero bit set -
                        both switches
                        pressed
    btfss PORTA,0       ; test if A0 is
                        pressed
    goto CX             ; A0 pressed
    btfss PORTA,1       ; A0 not pressed,
                        test if A1 pressed
    goto DX             ; A1 pressed
    goto EX             ; no switches
                        pressed
;
CX      btfss COLUMN,0      ; test if odd
                            or even
        goto CHEAT      ; even - wrong
        goto FX         ; odd - correct
;
DX      btfsc COLUMN,0      ; test if odd
                            or even
    goto CHEAT          ; odd - wrong
;
FX      call INCSCR     ; correct
    goto HX
;
CHEAT   movf SCRCTR,same
    btfsc STATUS,2      ; test if score =0
    goto HX             ; score = zero -
                        skip subtract
    decf SCRCTR,same        ; subtract 1
                            from score
    movf SCRCTR,w
    andlw 0Fh
    xorlw 0Fh           ; result will be 0 if
                        SCRCTR=xxxx
                        1111
    btfss STATUS,2
    goto HX             ; if not zero ie
                        SCRCTR not xxxx
                        1111
    movlw 0F0h
    andwf SCRCTR,same
    movlw 09h
    addwf SCRCTR,same
;
HX      movlw 80h       ; ie 1000 0000
    movwf LEDREG        ; switch off LEDs
    call DSCR
    movlw 0Fh           ; ie 0000 1111
    xorwf PORTA,w
    btfss STATUS,2
    goto HX             ; keys not released
    clrf BCREG
    movlw 0FFh
    movwf NCTR          ; reload NCTR with
0FF
    decfsz TRYCTR
    goto GX                     ; not finished
    clrf FLAG                   ; finished 99
tries ; enable display
    movlw 7Fh                   ; ie 0111
1111
    movwf LEDREG        ; switch on all
LEDs

FINISH  call DSCR
    goto FINISH
;
;*******************************************
;
    ORG 1FFh
;   goto START
;   END
```

Higher Education in electronics

SPECIAL

To conclude our short series on higher education in electronics, we look at courses with flexibility, including the American approach.

Publicity in recent months about colleges that now choose students on the basis of their GCSE results, as well as A-level results, has given new emphasis to the importance of GCSEs, the "first round" of major school qualifications. In the past, A levels have been emphasised as the chief passport to higher education, but with so many students now taking A levels, colleges are resorting to a wider angle of view on their applicants' educational histories. GCSEs are not so demanding or specialised as A levels, but they do provide a snapshot of the student's ability to handle a wider variety of subjects - for instance, it may interest a college if their prospective engineering or physics candidate also has a reasonable achievement in English or another modern language at a lower grade - something that A-level results alone would be unlikely to show, as science students are unlikely to have effort to spare to study languages at A-level as well as the necessary science subjects. Certainly, attempting to combine arts and sciences at A level is thwarted because it is beyond the resources of most schools, which find that allocating adequate timetable time "across disciplines" too difficult. Normally, only the biggest (or poshest) schools can offer much in the way of arts/science combinations at A level.

And then - after "which GCSE" or "which A level" comes "which higher course"? It's become axiomatic that, if you are doing a degree course in a university or college with a strong reputation, it matters less which subject and options you study, because employers can rest assured (they hope) that you will have honed your ability to learn and to handle new material. But in a highly specific and practical subject like electronics, you will also need to choose a course that covers all the basic requirements of the discipline, and to choose a speciality (if applicable) that can be applied to the career you wish to follow.

The question may be crucial to computer science students: whether to aim for a more theoretical and broad-based course, or to concentrate on learning the software languages that are currently in demand. While it is important to come away with some skills in languages and applications in current use, one of the sticking points for programmers is the ability to jump from a well-known language to a new one. Anyone who uses a spreadsheet or a CAD program will either have confronted the problem of "converting" to a new package, and knows the frustration and even fury that accompanies the new learning curve - or has that pleasure yet to come! In industry, it is the same on a larger scale, and a student who has already had some experience of transferring will be more attractive to high-tech employers.

There is no doubt that there is currently a boom in jobs for IT experts and programmers that is likely to last into the new millennium - but the new millennium is only three years away, and change is the name of the game, so get the best theoretical grounding and the best in-depth experience of languages, applications and operating systems that you can find.

Hull College

Hull College's proud boast is that they offer the largest range of further education courses in Humberside, full and part time. Hull is one of the breed of technically-oriented colleges that can provide education from GCSE level right up to degree level (in conjunction with the University of Hull), and also provides supporting options like Skillpower (number skills/communication/learning skills/life skills and computer skills) to prepare school leavers who have found their skills a little gappy for further study in NVQs and GNVQs, including technology and engineering options, and English as a Foreign Language (EFL) for students who do not have English as their first language and want to get their English up to speed. The four-year degree course in Chemistry, Applied Physics and Mechanical Engineering, Electronic Engineering and Computer Science is a four-year course, one year based at Hull College and three years based at Hull University, and is open to mature students without A-levels but with some career experience of engineering and physical sciences, as well as school leavers with GCSE and A-level qualifications.

In Hull, the emphasis in Electronics is in the School of Electronics and Telecommunications, which encompasses Electronics Servicing at various levels, a Telecomms Technician Certificate and a National Certificate, National Diploma and Higher National Diploma in Electronics and Communications. The School of Electrical Engineering concentrates more on electrical installation and manufacture, but offers a National Certificate in

Electrical/Electronic Engineering, and a short course in Electrical Safety for non-electrical craftspeople.

Hull also has a particular emphasis on motor vehicle engineering and fabrication (in a different section of the college) with a state-of-the-art vehicle fault-finding and simulation suite which also monitors the progress of students via the computer system! Extra funding has also been invested in a modern electronics training laboratory.

Hull College's prospectus and Engineering brochure give considerable detail about the different levels of further education in part time and full time courses and in modular programmes, and the further educational or career paths that they can lead to. Open days at the college are usually held once per term and twice in the summer term - contact the College for details.

University of Huddersfield

Huddersfield is an example of a University that provides degree and HNC/D (Higher National Certificate or Diploma) level courses in two- and three-year courses on a modular, part-time basis. Working students on day-release can expect to attend one day plus one evening per week, as well as end-of-session examinations, while others can choose their own pace of study, typically taking four modules per semester. For day release students, account is taken of work-based experience, and the supervised learning time is normally eight modules in the first year, with 30 hours per module. Third year Diploma students will cover four compulsory and three optional modules. The HNC/D course is particularly aimed at student who are already working in a career with practical day to day exposure to the area they are studying. These courses are mainly in computing and information technology. There is also a modular MSc course in Software Development, and another in Scientific Computing which in addition allows postgraduate students who are not working towards a further qualification to study course modules without seeking a qualification.

In Engineering, Huddersfield offers modular course in BEng (Hons) Computer-Aided Engineering, plus HNC Engineering in various fields including Electronic and Electrical Engineering and Manufacturing Systems.

The University emphasises that students must attend their classes regularly if they wish to continue on their course, and fees must be paid annually in advance. Modular learning at college, particularly at a postgraduate level, requires more discipline and commitment than "distance learning" and other self-funded, part-time courses of study, but the qualifications obtained are usually more sought-after - so it is not surprising that the Universities seek students with commitment.

Electronics Engineering: Aston University

Schiller International University

Schiller International University is an independent American university with campuses in the USA and Europe, based in Florida and accredited as a senior college by the Accrediting Council for Independent Colleges and Schools in Washington DC. SIU offers a great many undergraduate and graduate programs (a general term for USA courses, which are strongly modular in a way that has not yet caught on in the UK for full-time courses), particularly in business administration subjects.

At its London campus, SIU offers the first two years of the four-year course of study usually required for an American engineering degree. These two years, making up the Associate of Applied Science Degree, are referred to as pre-engineering because they precede the specialised parts of engineering study, are a standard part of American university engineering training. They include required courses in basic engineering, sciences, mathematics and general education. SIU students completing the first two years can then transfer to certain colleges in the USA, such as Western Carolina University and Clarkson University, to pursue the rest of the degree program.

To draw an analogy, this is roughly similar to reaching HND level before going on to study for a degree in the UK, having also completed a foundation year first - hence the four years. The contents of a US study program are not entirely like UK courses, and often provide a broader general educational base with a more flexible choice of optional courses throughout. To some extent, areas of study associated with A levels in the UK may appear in USA university programs, a direction which may in the future become more widespread in the UK.

The American system is not only modular, but is based on a system of course credits. One credit is the equivalent of 15 hours' classroom instruction, and a student must earn 124 credits to graduate with a Bachelor's Degree. To put this in perspective, as SIU's prospectus describes it, a student attending a history class for three hours a week for a full 15-week term and passing will receive three credits.

The top USA technical universities, like those in the UK, have a world reputation for state-of-the-art research and development, some of which is open to undergraduates. For those who feel a yen to study in the USA, the wise thing to do is to decide which college - in an ideal world - they would like to graduate from, and then find out from that college, what their entry requirements are, and which institutions in the UK or the student's home country they have an association with or regard with respect. Accredited USA and UK qualifications are valued all over the world, but removing from a course of study on one side of the Atlantic to the other does not provide an automatic "slot in position" and it is as well to know what might be required, in advance. Also, some UK colleges have links with USA colleges and arrange exchange programmes for a few months or a year for a certain number of students. US and UK higher education courses need a good level of spoken English, but many colleges can provide some tuition for students with good qualifications whose English needs "topping up" for study.

The future

With the recent news that many students will in future have to find money for their tuition fees in the UK (as is the almost universal arrangement elsewhere in the world) there is set to be

Electronics Engineering: Aston University

a scramble for college places before this becomes inevitable. This is set to make entry into higher education harder this year, with greater competition for places.

It could pay to speak to the Admissions office of the college or colleges you want to apply to and find out which courses cover the areas you want to study. There may be more options than you realise. Some more specialised (and less popular) courses have a considerable overlap both in content and career terms with more popular ones. And once you are in a college and have a track record as a serious student, it is often easier to change courses after your first year, or to take advantage of a vacancy in your first-choice course. That said, simply choosing a less likely course in the hope of switching later could backfire if the college is already over-subscribed.

What if you are not able to get onto a suitable course in 1997? Well, you may already have plans for a "year out", but if you do not, remember that colleges throughout the UK offer evening and part-time courses at reasonable prices. You may be able to use the opportunity to tighten up your maths, or improve one or two of your GCSE grades. Whatever happens, keep constructing - places will remain competitive, and all your experience will be of value in showing that you are the person for the place.

Although entry requirements for degree courses can be demanding, many are also negotiable, and most colleges will make allowances if they can see that the prospective student has a good work record and personal experience to back up his or her formal qualifications. This naturally applies to older students: for school leavers, colleges will need to see a reasonable learning record, but many technical colleges also offer provide background courses and foundation years to prepare for a higher level of study.

Good luck!

Contacts

Hull College, Queens Gardens, Hull HU1 3DG. Tel 01482 329943.
University of Huddersfield, Queensgate, Huddersfield HD1 3DH. Tel 01484 422288.
Schiller International University, Admissions, Royal Waterloo House, 51-55 Waterloo Road, London SE1 8TX. Tel. 0171 928 8484.

CITY University
SCHOOL OF ENGINEERING

MSc/Diploma in Information Engineering

This postgraduate course offers a set of integrated courses with a common theme in information acquisition and processing, systems and control with specialisations in Electronic Digital Systems and Communications, Control Engineering, Measurement and Instrumentation, Biomedical Computing, Instrumentation and Informatics.

The course is taken 12 months full-time, or over 24 months part-time, principally on a day release basis. A major feature of the MSc is an extended (5 months) project period.

See http://www-eeie.city.ac.uk or telephone 0171 477 8135 for further details. Department of Electrical, Electronic and Information Engineering.

Teaching and research excellence in London

Technology Education Index
40 Wellington Road, Orpington, Kent. BR5 4AQ
Educational, High Quality, Full Product Kits

Personal Stereo £19.95
Lessons include magnetic recording, audio amplifier theory, motor speed control, mechanical switches, and much more. Headphones included.

Talking Clock £19.95
This will teach you how electronic voices are made. Issues reports every hour, and includes an LED display and a choice of three different alarm sounds.

Motion Detector £19.95
This super sensor detector sounds an alarm when someone approaches the unit. Learn about motion detector technology. Uses a pyroelectric infrared sensor.

Digital Roulette £19.95
Just like the real thing! With the push of a button the LEDS spin round and round. It's unique design includes "pop-out" chips of different values.

Visit Our Web Site http//:www.technologyindex.com

All prices include VAT and carriage. Tel (01689) 876880 for further details
Please send me: Personal Stereo ☐ Talking Clock ☐
Motion Detector ☐ Digital Roulette ☐
I enclose a cheque for £.............(payable to "Technology Education Index")
Name...
Address...
....Post Code.............

VALVE CHARACTERISTIC Tester

PART 2

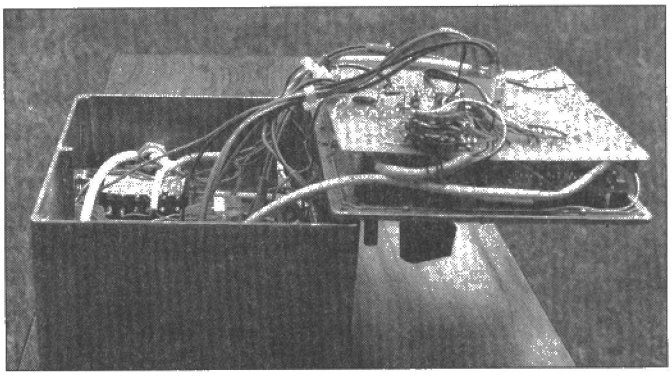
Peter Kenyon's valve tester assists in checking the essential characteristics of most types of electronic valve, and making up matched pairs.

In Part 1 of this article [ETI issue 8 1997] we described the functions of the Valve Characteristic Tester. This month's concluding part describes the construction and calibration of the Tester, and includes the Parts List and PCB

Construction

Before any components are installed on your pcb, it should be used as a template to mark out hole positions for the pots, LEDs and switches. You will need to make cut outs in the PCB at each side to accommodate the middle pillars of the Electromail box as used by the author, and also drill or ream out spindle holes so that parts of SW1 and SW7/VR7 can pass through the board. First, decide the exact position of the large rotary switch SW1. As the PCB is a close fit to the case, this is probably the trickiest operation in the mechanical construction. The wafers of the switch are mounted below the pcb (see figure 15). To retain the necessary stiffness of the switch assembly, the pillars and operating spindle pass through the board. Some extra "land" is available on the board for to allow room for the drilling. The exact position of these holes is not indicated on the pcb track layout, to allow some leeway for the constructor. As a guide, however, the hole can be approximately 1cm from the bottom edge of the pcb, but must not, of course, cut through or foul the tracks running nearby. Some space must be left between the end of the PCB and the wall of the box to allow connecting wires to pass through (or a slot filed out sufficient to allow the wires to pass). It is important that when the switch is fully assembled, the nuts should all be tight and secure for proper alignment of the rotors in the wafers. Another important consideration when deciding the switch position is to allow enough clearance for the wafer tags from the wall of the box. This type of diecast box has a taper, so that the base is narrower than the lid. As shown also in figure 15, the main pcb is below the valve socket pcb and, depending on their relative positions, the two boards overlap slightly. Near the centre of the main pcb are drilling positions for two 15mm stand off insulators or pillars. These are fitted during assembly, but are not strictly necessary once the rotary switch, SW2, SW3 and SW6 are wired and fitted. They do however reinforce the construction.

With the spacings shown, enough space is allowed for the Maplin DPM module to fit between the lid and the main pcb. The module is mounted on 10mm stand off insulators which are glued with two-pack adhesive, such as Araldite, to the underside of the lid.



A side view of the lid assembly showing the main PCB and DPM module in place. SW1 can be seen protruding below the lid and above the main PCB.

The switch mode heater pcb (figure 14), once assembled, can be positioned inside the case with the transformers and C1 in order to find the best layout. Be sure to mount IC4, D12 and IC5 at the same height above the pcb to enable easier alignment of the mounting holes in the side of the case. Note that L1 is secured to the pcb with a wire link. Since the switch portion of VR7 protrudes downwards into the case, allow for this when positioning T2. (Note also that VR7 is bolted to the pcb, while VR4, 5 and 6 are soldered.) Figure 15 shows a mechanical layout which makes for a straightforward construction. The fitting of some nuts and washers may require the extra dexterity afforded by a magnet or Blu-Tack on the end of a screwdriver. Before the small transformers are finally fitted, they must be fully wired and sleeved.

The internal layout shown in figure 15 gave the author a front panel layout as shown in figure 9 and the photograph. A suggested drilling guide for the more critical positions is shown in figure 12, although needless to say constructors should check the actual positions of their components in relation to the front panel before putting drill to metal.

The three valve sockets are available from PM Components Ltd. (see Parts List). Chassis punches are required for their mounting holes. The B7G is 16mm, the B9A 22.5mm and the International Octal is one and one-sixteenth inches.

The valve socket pcb can be wired to the sockets most easily with single core hook-up pin wire. Solder a short length to each of the mounted sockets. If they are all of a slightly different length, threading them through the pcb holes is made much easier. For the flying leads, use 13.5cm of flexible wire, passed through the box lid, sleeved and connected to a 2mm plug.

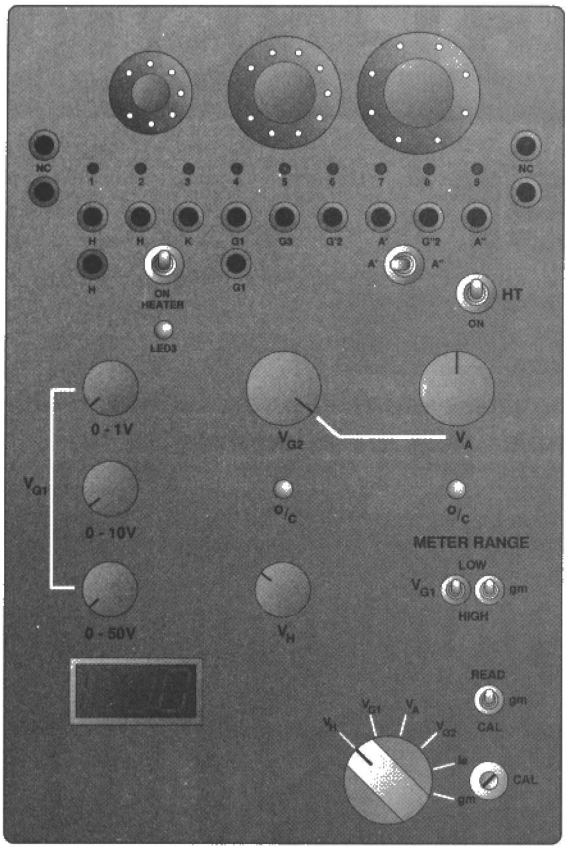
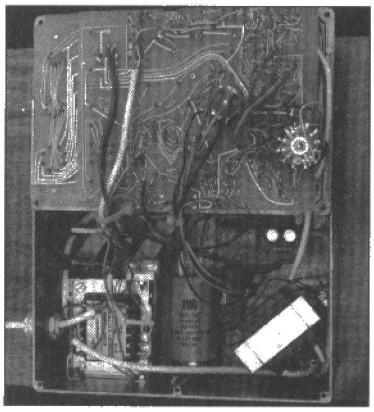


Figure 9: how the author laid out the front panel

The main PCB

Assemble the main pcb, beginning with low profile components and finishing with the large ones. Don't omit the links. Note that two of the links take + and -12 volts to IC7. They go from pads adjacent to C3 to pads adjacent to C34 and C35. The polarity is obviously important.



A view of the internal layout and the rear of the main PCB. The main PCB has been trimmed to clear pillars and corner fixings in this case, and to allow wiring to pass the board at the lower edge. SW1 is mounted through the land along the bottom edge.

Begin the construction of LED4 and LDR1 by cutting a 2cm length of Maplin low temperature heat shrink sleeving. Add a circular blob of Blu-Tack close to the body and around the leads of both LED4 and LDR1. Push both an equal distance into the heat shrink sleeve until they come into close contact. A hair-dryer directed evenly over the heat shrink will make a compact light proof unit. Connect a multi-meter on a high ohms range to the LDR to ensure that light is excluded. A reading of at least 1 megohm in ambient daylight will be adequate. Check the polarity of the LED then bend the leads at right angles for insertion into the board. VR1, VR2, VR4, VR5 and VR6 are soldered close up to the pcb while their spindles are fitted through the lid. This will ensure that no stress is placed on their pins and that the spindles will not bind.

Assuming that you have fixed the position for SW1, the rotary switch, assemble the switch to the pcb with its pillars and install the upper wafer (sections a and b). These sections can now be wired to the track side of the pcb with ribbon cable. Note that the connections are numbered 1 to 6 on the component layout and, as you view the wafers from below, the tags are numbered in an anti-clockwise direction. Be sure to locate the correct traveller for each section. The connections between SW1d and switches SW5b and SW8b are hard wired; SW5 and SW8 are conventionally mounted on

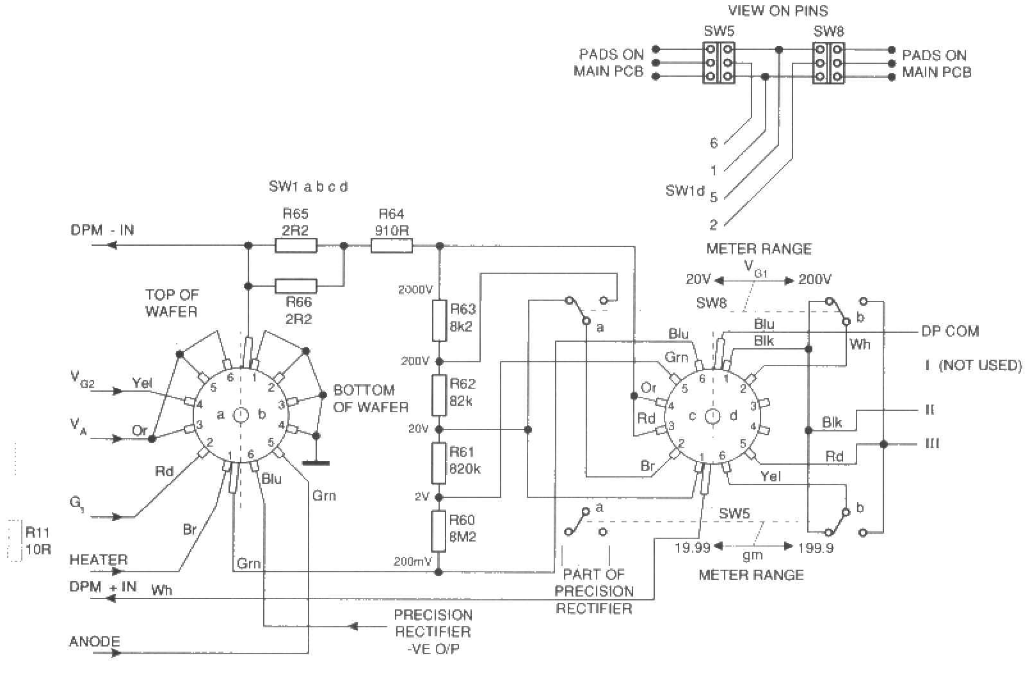


Figure 10: the DPM switch wiring

PARTS LIST for the Valve Characteristic Tester

Resistors

R1	4.7R
R2, R16,R35, R37, R39, R53	1k
R3, R7, R25, R26, R27, R30, R34, R36, R38	10k
R4, R6	6.2k
R5	82k
R9, R57	220R
R10	47k 2W
R 11	10R 0.1 percent precision Electromail
R12, R15, R18	2.2k
R13	100k 2W
R14, R20, R51	56k
R17	1.8k
R 19	220R 2W
R21, R28	22k
R23	270R
R24	22R
R29	5.6k
R31, R33, R44	100k
R40, R56	220k
R32, R45	33k
R43	1.5k
R46	330k
R44, R47, R48	39k
R49, R50	68k
R52	150R
R54, R55	470R
R58	3.9k
R59	1k
R60	8M2
R61	870k
R62	82k
R63	8k2
R64	910R
R65,66	2.2R
R67	4.7k
LDR1	NS119-MS51 Electromail 596-141

Potentiometers

(All variable pots from Electromail)

VR1, VR2	220k 2W cermet
VR3	1k cermet preset 32961
VR4	47k 2W cermet
VR5	10k 2W cermet
VR6	1k 2W cermet
VR7	22k lin + dpst switch
VR8	50 ohm cermet preset 3296X
VR9	5k cermet present 3296X
VR10	1k 2W cermet
VR11	1k cermet preset 3296X

Capacitors

2, C28	220uF 35V Maplin AT60Q
C3, C4, CS, C29, C30	10uF 16V tant
C6	33nF 250V
C7	(omitted)
C8, C9	1uF 450V Maplin VH17T
C10	10uF 100V
C11	2200uF 35V
C12	100uF 50V low ESR Maplin J149D
C13, C16, C22	220nF polyester
C14, C15,	220uF 50V low ESR Maplin JL51F
C17,18	2.2nF polystyrene
C19, C20	1uF 35V tant
C21,C33,C34, C35	10uF 16V tant
C23	10nF ceramic
C24,C25,C26	100nF polyester
C27,32	10uF 25V tant
C31	10nF 400V polyester BX70M

Semiconductors

IC1	MC1458N
IC2, IC8	78L15ACZ
IC3, IC9	TLE2426CLP
IC4	LT1074CT
IC5	LM317T
IC6	LF353
IC7	TLE2072CP
IC10	4N25 opto-isolator
IC11	TL431C
Q1	BUK454-600B
Q2,Q6	BC550
Q3	MJE350
Q4	BC559
Q5, Q7	BS170
D1, D10, D11	1N4005
D2, D4	6.2V zener 500mW
D3, D21	9.1V zener 500mW
D5	J511 4.7 mA constant current diode Electromail
D6-9, D13-20	1N4148 Maplin UK63T
D12	BYW80-150
BR1-BR5	DF06M 600V IA bridge Electromail 183-4034
BR6	W005G 50V 1.5A bridge
L1	150uH

Transformers

T1	250V l00mA, 15V 1.5A, 6.3V 1.5A Maplin ST29G
T2	9V + 9V 1.38A Maplin DH26D
T3, T4	24V + 24V 6VA Electromail 804-931

Switches

SW1a,b,c,d	4-pole 6-way rotary switch, break before make
SW2, SW3, SW5	dpdt 250V 2A toggle switch
SW4	spco signal switching toggle
SW6, SW8	dpco signal switching toggle
SW7	dpst switch (part of VR7)
SW9	dpst 250V 1A toggle switch

Miscellaneous hardware

Case	Die-cast box 222mm x 146mm x 106mm Electromail 225-265
SK1	B7G valve socket
SK2	B9A valve socket
SK3	10 International Octal socket
DPM	Maplin module GW01B

SK1, 2 and 3 are from PM Components Ltd., Selectron House, Springhead Road, Gravesend, Kent DA11 8HD.

Most other parts are available from Maplin Electronics PO Box 3, Rayleigh, Essex SS6 8LR tel 01792 554161, or

Electromail, P O Box 33, Corby, Northants NN17 9EL Tel 01536 405555.

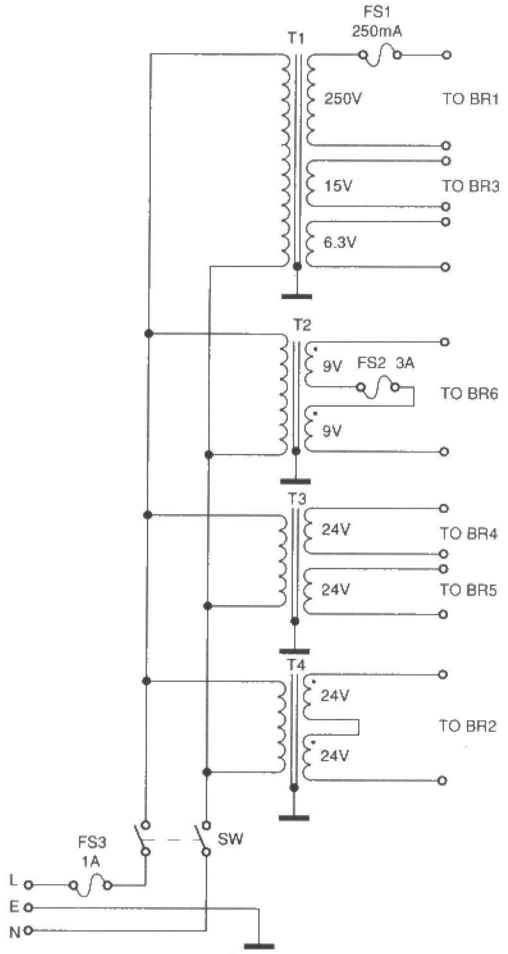


Figure 11: connecting the power transformers

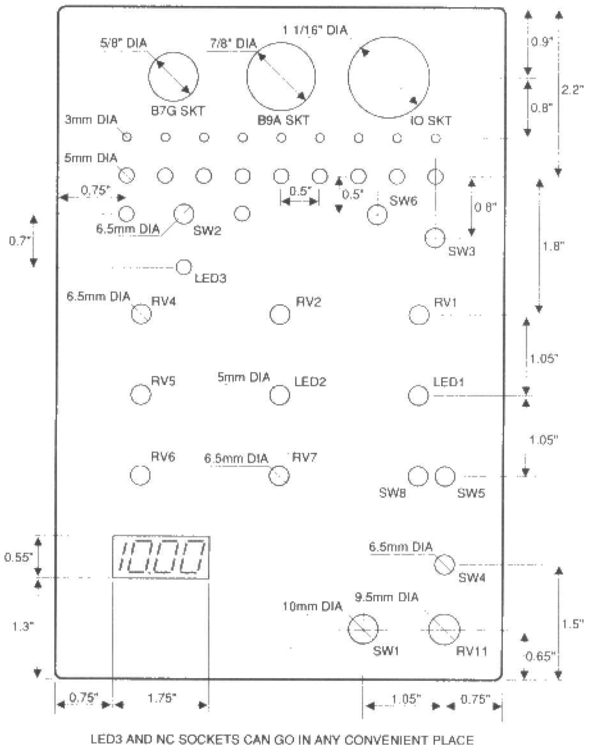


Figure 12: a front panel drilling guide

the lid. The DPM switch wiring is shown in figure 10. The connections to the decimal point links on the DPM pcb are also hard wired.

As an aid to construction, I suggest turning the lid upside down and securing it to the right hand side of the box with one of the fixing screws. This also ensures that wires linking transformers with pcb pads, for example, will be long enough.

Bolting transformers, capacitors and other items into place will require screws of 3mm (for power transistors), 4mm (for transformers) and 2mm nuts, as additional fixings for the rotary switch.

Switches SW2, SW3 and SW6 are best wired lastly to the pcb. 1.5cm lengths of single core insulated hook up wire are soldered into the board. Mount the board in position and

manoeuvre the wires onto the switch tags bolted into the lid. A slim soldering iron is necessary to accomplish this. Dismount the pcb from the lid. Push the three LEDs into the pcb and solder one leg only at full length. Re-position the pcb onto the lid and move the LEDs as necessary so that they protrude about 3mm above the lid surface. Solder the LEDs in position.

The HT fuse FS1 is Maplin item KU29C, and is bolted to one hole of the mounting frame of T1. Add sleeves to its connecting wires. This type has an insulating cap.

Use flexible 16/0.2 cable for connections between the heater board and SW7 and duty flexible cable for VR7. With the tags of VR7 facing you, the left and centre tags are linked and the two board connections go to the centre and right tags. As a check, this should give you minimum pot resistance when anti-clockwise.

DPM Assembly

With the spacings shown in figure 15, enough room is allowed for the Maplin DPM module to fit between the lid and the main pcb. The module is mounted on 10mm stand off insulators which are glued with a two-pack adhesive, such as Araldite, to the underside of the lid. Remove the main pcb from the lid, and position the DPM over the window which you have cut for it. Connect the battery to the DPM so that the digits show. With the aid of a small mirror, the exact position can be found. Clean the area where glue will be applied, and with long 3mm screws holding the stand offs to the DPM, glue the stand offs into place.

An alternative to using the DPM is a regular digital multi-meter. Omit R60 to R66 inclusive, and instead fit a pair of appropriate sockets to the lid. Connect these to DPM+ and DPM- as shown in the diagrams, and an external meter will make your measurements. It should have the generally standard input resistance of about 10 Mohms. Remember that you will have to switch ranges on the multi-meter as SW1 is changed. The required ranges are as follows:

Vh	20 volt range
Vgl	20 volt or 200 volt range
Va	400 volt or 1000 volt range
Vg2	400 volt or 1000 volt range
Ia	200 mV range
gm	200 mV range

Testing, setting up and calibration

Temporarily disconnect the earthing lead between the pcb and the case. Ensure that you have fitted mica washers and insulating kits to all transistor and ic tabs. Check for good insulation between each of the transistor tabs and the case

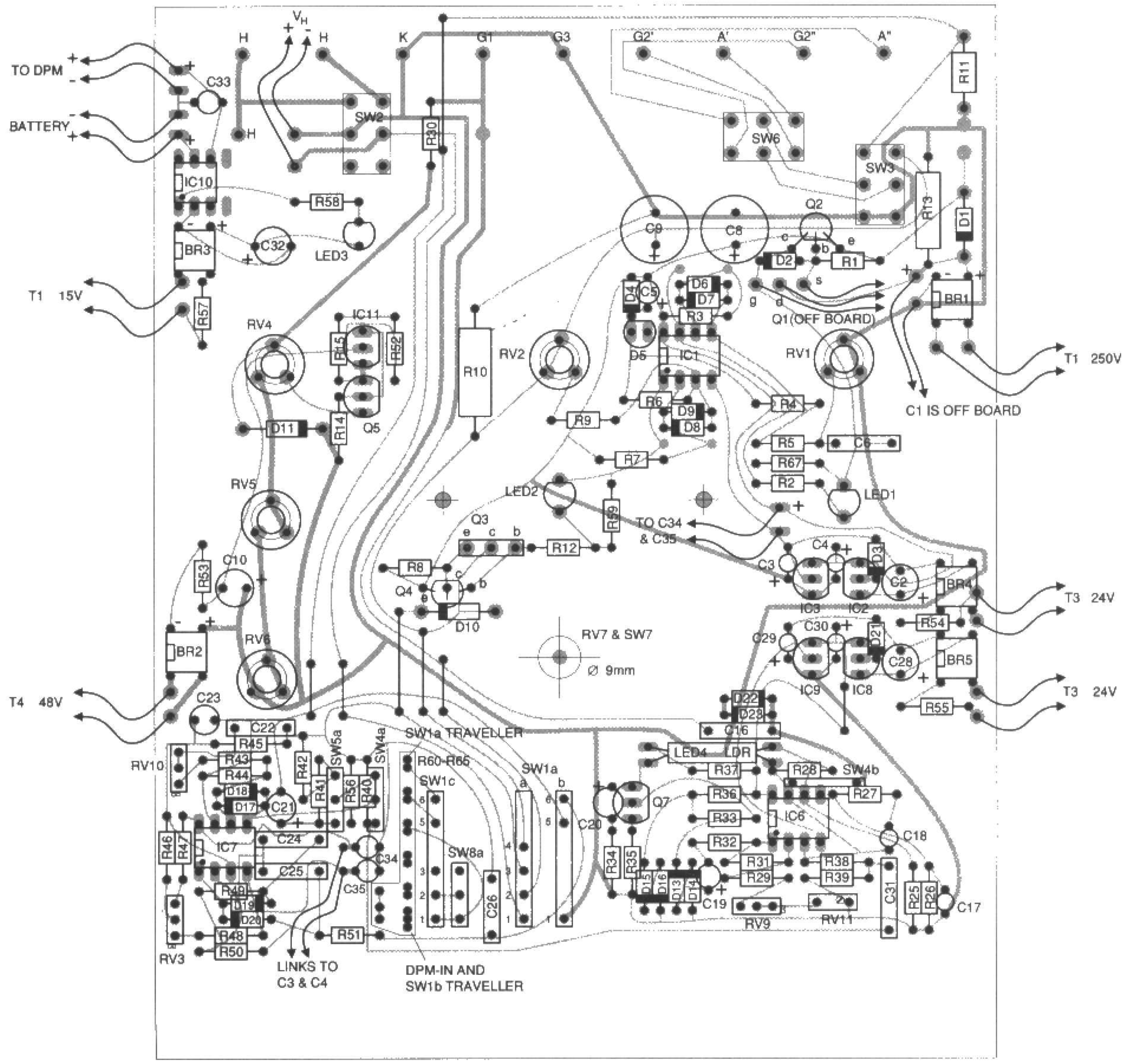


Figure 13: the main PCB component layout

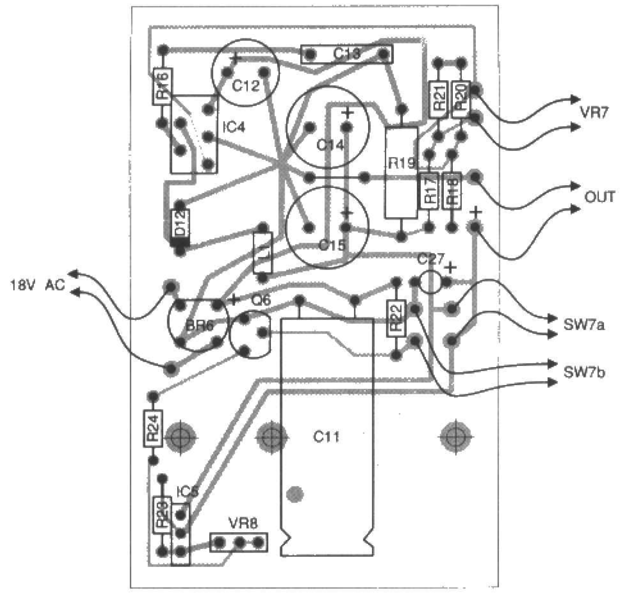


Figure 14: the heater regulator PCB component layout

(infinite resistance). If all is well, the switch mode heater board can be tested. Restore the case to main pcb earth connection.

Rotate VR7 fully anti-clockwise to its "off" position. Fit a fuse to F52 and apply power. Adjust VR8 preset on the heater board for 1.4volts output voltage. Rotate VR7 to the "on" position and check that the output voltage can be adjusted between 4 volts and 20 volts (fully clockwise).

Rotate VR4, VR5 and VR6 fully anti-clockwise. With a multi-meter across D11, turn VR4 and check that up to 1 volt appears across D11. Likewise, VR5 should add up to I volt and VR6 should add up to 50 volts.
Check the correct appearance of +12 volts and -12 volts at IC1, 1C6 and IC7 pins 8 and 4 respectively. Remove mains power before proceeding.

Before applying the HT voltage to the board, it is advisable to remove the 8-pin ics from their sockets in case you have any accidental solder bridges. In any case, inspect your work carefully. The flying lead connections to Q1 must be sleeved and well insulated.

Fit a 250mA fuse to FS1 and apply power. A voltage of about 350 volts should be present across C1 and, assuming

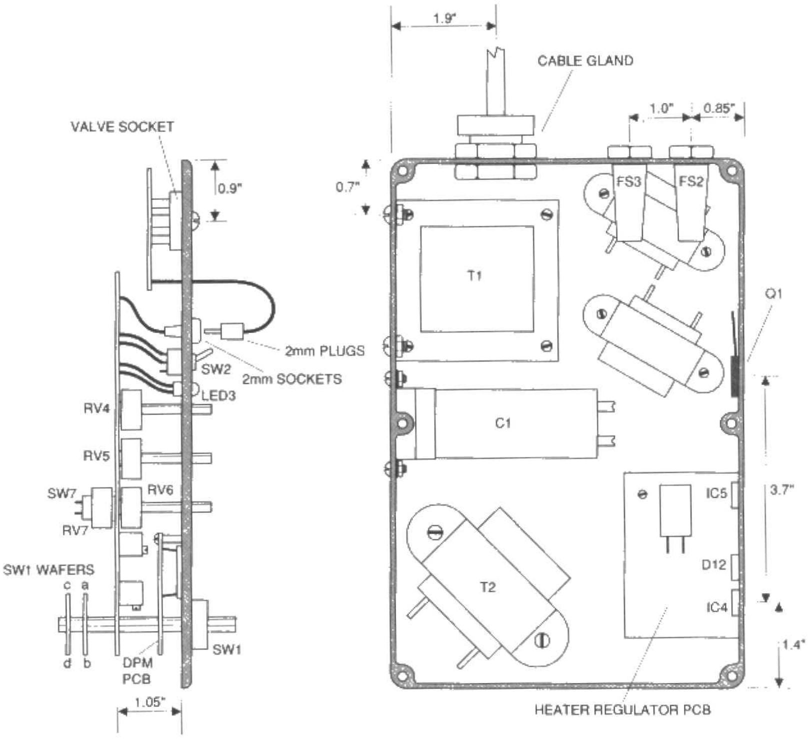


Figure 15: a mechanical layout

that you have removed the ics, no voltage should appear at the source of Q1. Remove mains power, insert the ics and check that the HT voltage can be varied between about 80 volts and 300 volts when VR1 is rotated. With VR2 fully clockwise, Vg2 should be the same as Va, and should reduce as VR2 is rotated anti-clockwise. It should also track Va with a constant difference between the two voltages as previously explained. Note that LED2 will light when VR2 is fully clockwise. This is normal.

The oscillator section

If your multi-meter will reliably measure a 7kHz signal it can be used to set up the oscillator section. Set VR11 on the lid to mid-position and adjust VR9 preset for 100mV at pin 7 of IC6. An oscilloscope can be used alternatively for 283mV pk-pk at IC6 pin 7.

With SW4 in the READ position, adjust VR3 preset for a reading of 0.00 on the DPM. Now switch SW4 to CAL and adjust VR10 for a reading of 10.00 on the DPM. If you have access to neither a high frequency multi-meter nor an oscilloscope, position VR9 and VR11 half way and adjust VR10 for a reading of 10.00 on the DPM, having first adjusted VR3 for zero. It may be necessary to move VR9 one way or the other while adjusting VR10.

When you are satisfied with your adjustments, the single wire connections from the pcb heater, cathode, control grid, screen grid, g3 and anode pads to the 2mm sockets cab be made. Thread a ferrite bead (Maplin LB62S) on each of these wires before soldering.

Note that in addition to the eleven electrode connections, there are four extra 2mm sockets shown on the front panel. These are not connected and are used for those 2mm plugs left over when the pin assignments have been made or for valve internal connections, sometimes referred to as IC or ic.

When double valves are tested, one cathode should be plugged to K and the other to g3, while the two control grids should be plugged to the two g1 sockets. The two sections are then tested individually by means of the a'/a" switch. For a single section valve this switch should be in the a' position.

An addition has been made to the Valve Characteristic Tester circuit since the schematics appeared in Part 1, due to the author's interesting experience with a faulty valve under test. Two 1N4148 diodes, D22 and D23, have been inserted between pin 7 of IC6 and the 0 volt rail to protect the output of IC6a. These appear on the component layout (Figure 13) and the PCB, which appears this month, has been updated.

In the author's suggested layout for the front panel (figure 9), the 0-1V pot should appear next to the panel meter and the 0.50V pot at the top of the sequence.

Reference

Suitable reference sources for valve parameters include the 'Radio Valve Guide' compiled by the staff of Wireless World (1949, with further editions), valve suppliers, and in some cases the manufacturers. The Radio Valve Guide is as far as we can ascertain out of print, but copies can sometimes be obtained from libraries or second hand bookshops (or borrowed - with care!). The book service of Radio Bygones magazine (G C Arnold Partners, tel 01202 658474) can also provide reprints of some out of print valve data, plus much other information of interest to the real enthusiast.

SPEED CONTROL in DC Motors

PART TWO

In Part one, David Ponting's final circuit provided a constant drive to a DC motor under varying loads, but only at one running speed: 7.5 inches of tape per second. This month he goes in search of 3.75 and 15 inches per second.

In part one of this article [ETI issue 9 1997], I described three circuits which were designed to control the speed of small DC motors, specifically those which include a tachometer as part of their construction.

My interest in this subject was aroused when I was given an ancient but magnificent reel-to-reel tape recorder whose capstan motor had burnt out. Replacing this motor with an exact equivalent would not have been easy, and in any case the original was intended for use in the United States and designed to provide the necessary constant speed by being driven synchronously with 60 Hz, the frequency of American mains. With Europe using 50 Hz mains, an exact equivalent motor for my tape recorder when used in England would lock to 50 Hz, and so run at only 5/6ths of its standard speed.

Finding a tach-fitted DC motor with suitable power and of a size to fit into the available space in my tape recorder was not difficult. What was far from easy was finding a way to drive it at a speed which is not only constant, but remains so under the varying load caused as the supply tape spool goes from full to empty.

The final circuit described in the previous article locked the output frequency of the motor's tachometer to a standard frequency derived from a crystal. Even with that solution, the problem still remained that, while the circuit would provide a constant drive to a DC motor under varying loads, it could not easily be adapted to provide more than the single running speed of 7.5 inches of tape per second. The recorder would be of greater use if I could devise a constant drive circuit which also allowed the transport of tape at the standard speeds of 3.75 and 15 inches per second.

There were other minor problems too. Comparing two close frequencies results in "beating", and this new low frequency, together with mains-induced hum, can cause the motor speed to jitter somewhat.

A different tachometer

The motor I have described so far was one where the tach was simply a small AC generator which, as the speed of the motor varied, produced both varying frequency and peak-to-peak voltage. Another motor I found was fitted with a different kind of tach where a slotted disc rotates between an LED and a photo-transistor. As the slots and "teeth" alternately illuminate and cut off light to the transistor, pulses are produced and the frequency of the pulse-train is a measure of the speed of the motor. In fact, this tach outputs two wave-trains, each producing 500 pulses every revolution, or a frequency of 15,000 Hz at 1800 rpm, which is the required shaft speed to drive tape at 7.5 ips. For the other two speeds of 3.75 and 15 ips, the frequency of each wave train would be 7,500 and 30,000 Hz respectively.

So here seemed to be a way to compare the frequency of one of these trains with that from a standard crystal clock divided down to 7,500 Hz.. At the slowest tape speed, I thought I would simply lock the two frequencies directly; for the centre speed, I would divide the 15,000 by 2 before comparing them and at the highest speed, divide the 30,000 by 4 before comparison. But it does not work!

The problem is that at these relatively high frequencies, the natural jitter of the motor (caused mainly by hum and random friction) has a frequency about the same order as 7,500 Hz. In consequence, the tach and the divided clock frequency lock together initially, but only milliseconds later, as soon as any jitter occurs, the lock is lost, and the motor speeds away out of control.

However, dividing the motor's 7,500 by 2 and halving the clock speed before comparison means that jitter has to last twice as long before lock is broken. The result will still be very unstable, but less so than previously. Dividing both tach and clock again improves stability even more, and repeating this process results in the lock getting better and better.

The question then becomes: how far can you take this division?

Using the mains

Let us look at this question when related to the other problem that I had encountered: instability related to mains hum. This I had had great difficulty in reducing, let alone eliminating. So, following the maxim "if you can't beat 'em, join 'em", I reasoned that I could lose mains hum completely if I used the mains frequency as the standard clock. Of course that would mean I would have to find some way to divide 7,500 down to 50. And if I could, would there still be a good solid lock for division down as low as this?

I also saw that even if this solution worked well, my tape recorder would be useless in North America, where the standard clock would be 60 Hz. Or was there some way to divide the 7,500 from the tach down to 50 in this country and to 60 in the United States? It all seemed as if it might become very complicated, particularly when division by factors other than 2 and 10 can involve considerable logic.

But there are programmable divider chips and perhaps one of the more interesting is the cmos 4059. This is a divide-by-N counter where N can be any whole number between 3 and 15,999. It has 24 pins of which 19 determine the divisor, the others being power, ground, clock-in, divided-clock-out and enable.

Programming the 4059 can appear to be a highly daunting prospect, but fortunately for our purposes this can be greatly simplified

Table one

Mode	Pin 14	Pin 13	Pin 11
2	H	H	H
4	L	H	H
5	n	L	H
8	L	L	H
10	H	H	L

The first thing to decide (somewhat randomly) is what the first divisor (called the MODE) shall be. The MODE can be 2, 4, 5, 8, or 10, and it is not a requirement that division of the dividend by whatever MODE is chosen must leave no remainder.

For simplicity, select a MODE which after dividing N by your choice produces a number below 2000 (together with a remainder, if there is one). The programming either High or Low of pins 14, 13 and 11 determines the MODE. (See table one).

An example may make things clearer.

For some inexplicable reason, let us suppose that we want to divide a frequency by 7863.

First, select the MODE. Let us not choose 2, because the result will be greater than 2000. We can choose any of the others, so let our MODE be 5. From table one, we see that pins 14, 13 and 11 must be connected High, Low and High respectively for this MODE.

To arrive at the connections for the other pins, we divide 7863 by our MODE and get 1572, remainder 3.

The programming of the remaining pins for the complete division is set out in table two.

Note that if MODE 10 is chosen, it is possible that N/l0 will result in a remainder of 8 or 9. However, the "Remainder" column in table two is limited to numbers 7 and smaller. There are ways around this, but make life easy and choose another MODE.

Five pins remain. The power pins are positive to 24 and ground to 12. For division, the ENABLE (Pin 2) must be held low. Provided the signal into Pin 1 (the clock input of the 4059) is free from random noise and each pulse has only a single rising edge, the frequency of the output from Pin 23 will be the clock signal divided by 7863.

Unfortunately, the shape of the divided waveform emerging from Pin 23 is not at all satisfactory from our point of view. Figure one explains the problem.

Table two

First Digit	Second Digit	Third Digit	Fourth Digit	Remainder
1	5	7	2	3
Pin 6	Pins 7 8 9 10	Pins 15 16 17 18	Pins 19 20 21 22	Pins 5 4 3
H	L H L H	L H H H	L L H L	L H H

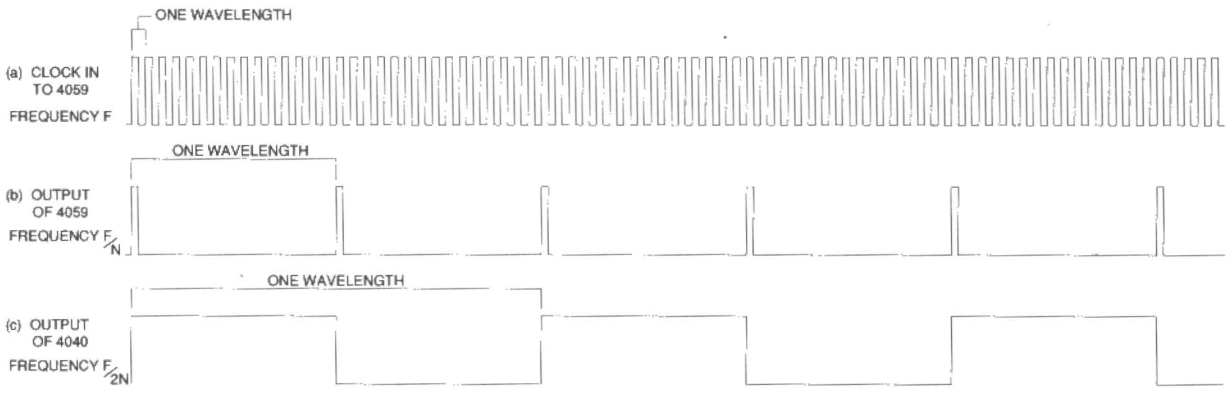


Figure 1: problems with the waveform first emerging from Pin 23

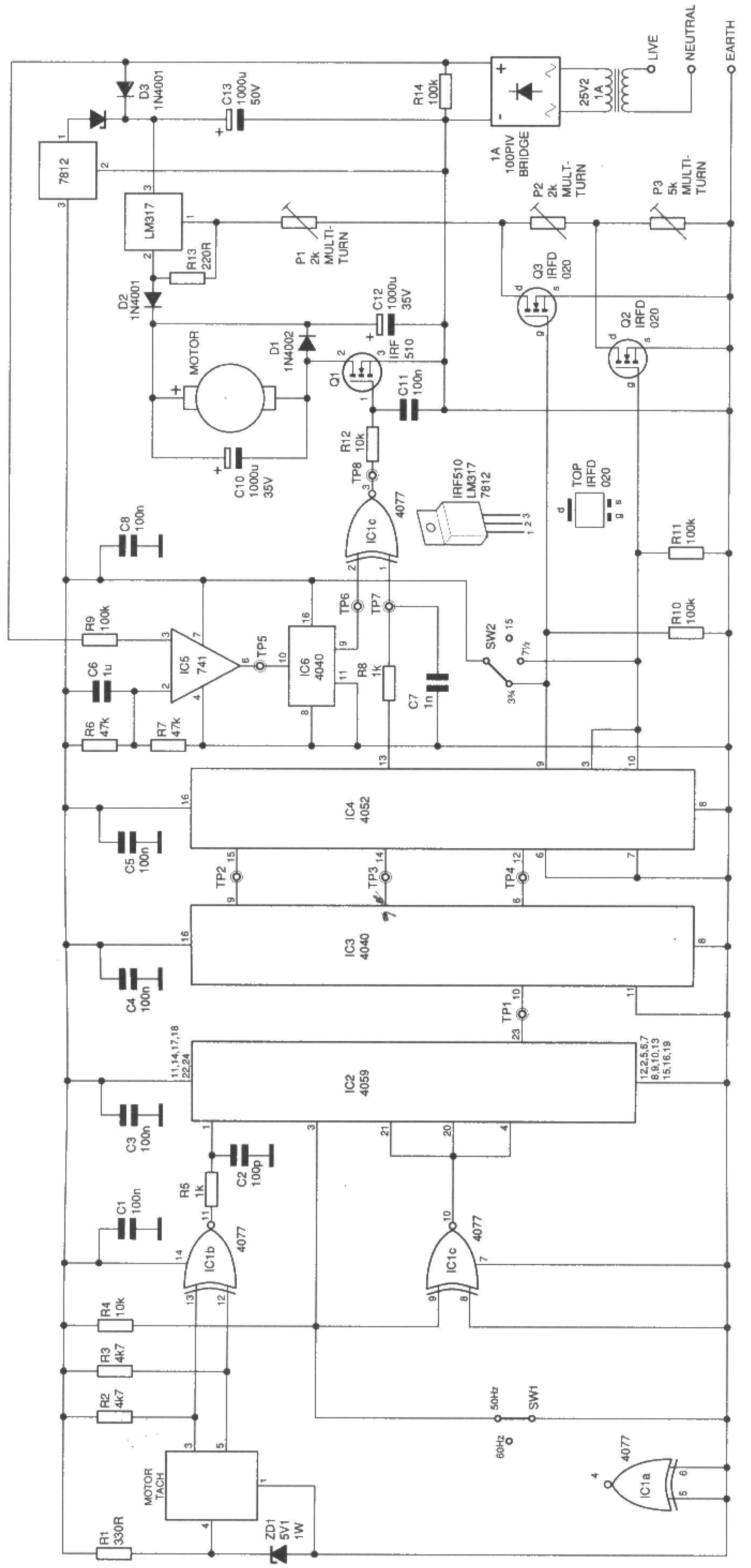


Figure 2: the circuit

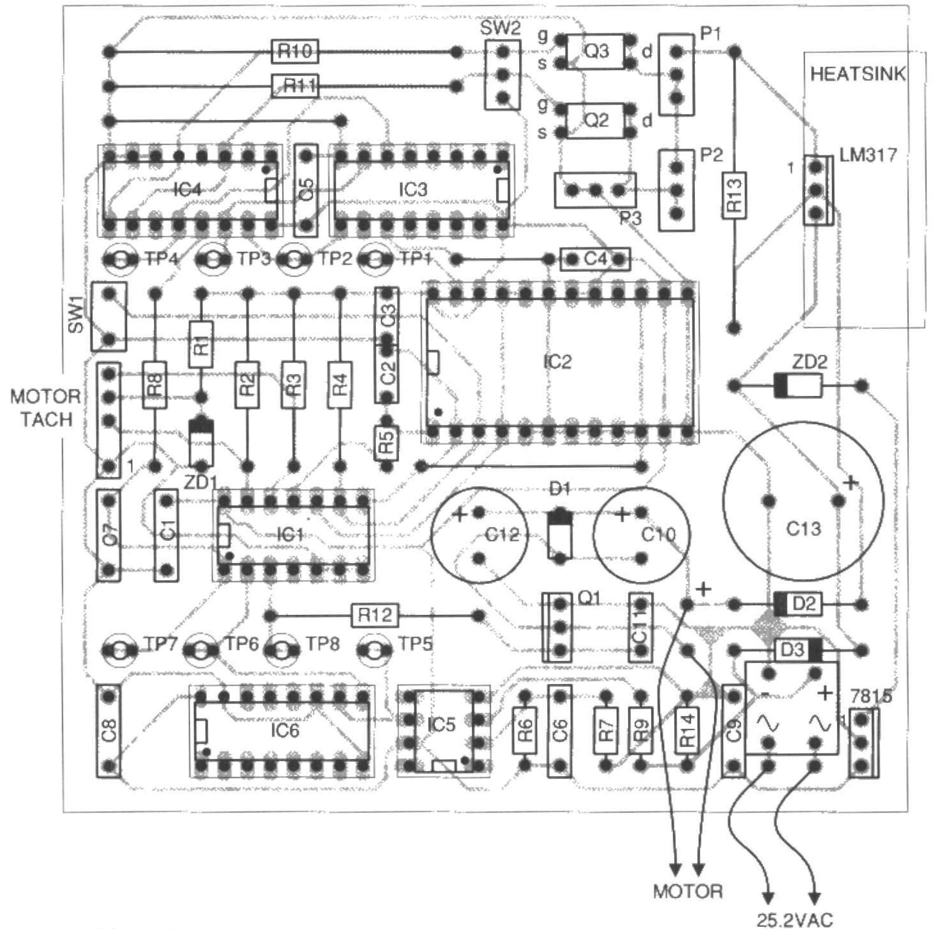


Figure 2a: the component layout

Tracing divisions

The top trace in figure one shows the clean clock input into the 4059. The second trace shows the divided output: very far from the 50 percent duty cycle wave that the frequency comparator input requires.

Division in the 4059 is achieved by the chip outputting a pulse, waiting until it has counted one fewer than the divisor pre-set by the programmed pins, and then outputting the next pulse. The result is the correct division of the input frequency, but each output pulse is only the width of the original clock signal.

The method of achieving the 50 percent duty cycle we require is shown in the third section of figure one. Using another chip, a 4040, we divide the output of the 4059 by 2. The leading edge of the first narrow pulse from the 4059 is used to set the 4040's divide-by-2 counter, and the next leading edge resets it. This results in a perfect 50 percent duty cycle wave out of the 4040 but at only half the frequency we require. This can easily be corrected by reducing by a factor of 2 the divider set in the 4059.

It all sounds much more complex than it really is. For example, in the case of the motor I was using, the required lowest tape speed of 3.75 ips produced an output from the tach of 7,500 Hz. This has to be divided down both by the 4059 and by the 4040 divide-by-2 counter to match the mains frequency of 50 Hz. So working backwards, if the output of the 4040 must be 50, its input must be 100. If the input into the 4059 is 7,500 and its output is to be 100, the chip must be programmed to divide by 75.

For the higher speeds of 7.5 ips and 15 ips the tach outputs 15,000 and 30,000 Hz respectively. Keeping the division by the 4059 constant means that it will divide these by 75, giving respective outputs of 200 and 400. Fortunately, two other pins on the same 4040 provide division by 4 and 8, and so make available tach frequencies which match the 50 Hz mains clock.

All we need is a 3-way switch to select the appropriate output pin of the 4040 to correspond with the chosen tape speed of the recorder.

Figure two shows the final circuit for the project. All the ics on this PCB should be fitted into sockets. This also allows some simplification in the design.

Trimming the sockets ...

When making the board itself, it is sometimes very difficult to lay a track between ic pads without producing a short circuit. In this design, many ic pins remain unused. Consequently when I needed to put down a track between ic pads and there was a convenient unused pin nearby, I removed the unused pin. This is best achieved in practice by simply pushing the unwanted pin carefully out of the ic socket from below.

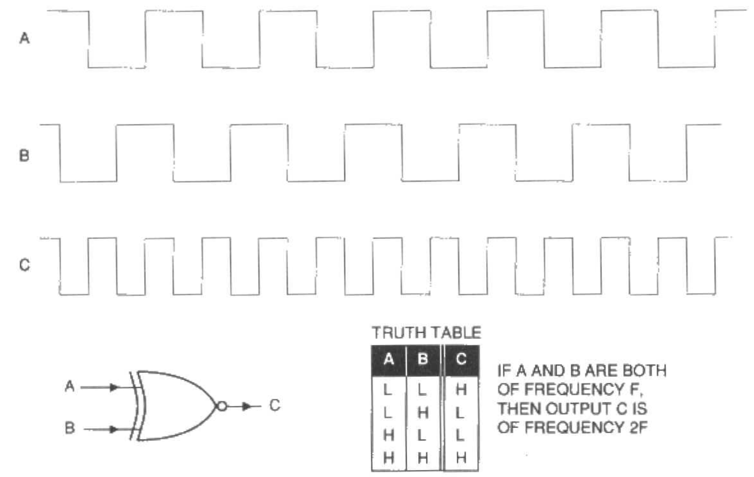
Such action, of course, has no effect on the workings of the ic, but if you feel that this constitutes poor practice, two small changes to the PCB design for IC4 and IC6 should be made to replace the missing pads, and then the tracks can be routed between them. (The PCB provided by the PCB Service follows the author's original design. If you have the type of ic socket that will not allow the pins to be pushed out, you can cut unwanted pins close to the body of the socket if you have a close-cutting pair of wire snips. Check that the pin stub is not shorting to anything. As this is a single-sided board, this should not pose a problem in this case. Make any adjustments before soldering the socket, and before fitting the ic.)

How it works

In general terms, the circuit follows the same lines as previously described circuits, but there are one or two things that perhaps need explanation.

First of all, programming IC2, the 4059. In my previous article I said that I might want to use my restored tape recorder in the United States. For this, I had to have some way of dividing the input down to both 50 Hz and 60 Hz, the mains frequency in America. Of course the motor would still output 7,500, 15,000 and 30,000 for the tape recorder's three speeds, but two separate divisions by the 4059 would be required to accommodate the different mains frequencies.

So let us repeat the process for a mains frequency of 60 Hz, again working backwards. For the slowest speed the output of the 4040 had to be 60, its input therefore needed to be 120 Hz. So 7,500 had to be divided by some whole number resulting in 120. And this of course is the problem, because that divisor turns out to be 65 5. Oh dear! However, if I could double the frequency of the motor's tach, so that the slowest output became 15,000, division in the 4059 would be by the whole number 125 for an output of 120 into the 4040.



A	B	C
L	L	H
L	H	L
H	L	L
H	H	H

IF A AND B ARE BOTH OF FREQUENCY F, THEN OUTPUT C IS OF FREQUENCY 2F

Figure 3: putting two pulse trains from a tachometer into an exclusive-NOR gate

As it happened, doubling the tach's frequency was easy to achieve:

As I mentioned above, the tach on my motor (in common with many motors having optical tachometers) outputs two separate pulse trains, but these are arranged to be exactly 90 degrees out of phase. The usual purpose for this is to allow the determination of both speed and direction-of-rotation of the motor. I was only going to use the motor rotating in one direction, so I could use both pulse trains to control the motor's speed.

Figure three shows how inputting the two tach trains into an exclusive-nor gate results in a 50 percent duty-cycle pulse train with twice the frequency of the inputs.

Referring back to the circuit diagram, the internal circuit of the tach requires a 5 volt supply and this is produced by RI and ZDI. R2 and R3 pull up the output pulse trains from 5 volts to cmos level and Gate N2 "adds" them together. This output passes into Pin 1 of the 4059 via the low-pass filter, R5/C2.

Now let us work out how the 4059 must be programmed for division to provide 100 for 50 Hz and 120 for 60 Hz.

The doubled output of the tach for the slowest tape speed of 3.75 ips is 15,000. So our divisors are 150 to get 100, and 125 to get 120.

Using the technique described above, we select a MODE, say 4. This has to be divided first into 0150 and then into 0125, considering both as 4 digit numbers. The results are 0037 remainder 2, and 0031 remainder 1. From table one above, MODE 4 is programmed by connecting Pin 14 Low, and Pins 13 and 11 High. Table Three gives the connections for the other pins.

From Table 3, above, we can see that only the four pins, 20, 21, 4 and 3, change in switching from division by 150 to division by 125. Gate N3, R4 and the ON/OFF switch, SI, form the simple logic allowing reversal of those four pins.

The output from the 4059 is connected to Pin 10 of 1C3 which reshapes the pulses to a 50 percent duty-cycle, and makes available at pins 9, 7 and 6 the further division of the pulse-train frequency by 2, 4 and 8 respectively.

IC4 is used here as the chip equivalent of a one-pole, three-way switch. (The same chip can be extended to two-pole, four-way, if required.) SW2, which switches the logic at Pins 9 and 10, determines which of the three inputs at Pins 12, 14 and 15 is routed to the output

Table three

Clock	First Digit	Second Digit	Third Digit	Fourth Digit	Remainder Frequency
	Pin 6	Pins 7 8 9 10	Pins 15 16 17 18	Pins 19 20 21 22	Pins 5 4 3
	0	0	3	7	2
50 Hz	L	L L L L	L L H H	L H H H	L H L
60 Hz	0	0	3	1	1
	L	LLLL	LLHH	L L L H	L L H

at Pin 13. (Pin 3 is the unused pole of the other internal switch, and, to prevent random switching, is tied to Pin 10.)

The position of SW2 also determines the total resistance in the Pin 1/Earth lead of the LM 317, a variable voltage regulator. If SW2 is at its 3 75 position, Q3 is on, and so the total resistance is the value of P1. This is adjusted to provide an output from the LM 317 of about 9 volts. If SW2 is at its 7 5 position, Q2 is on and Q3 is off, and so the total resistance from Pin 1 of the LM 317 to Earth is (PI + P2). P2 is now adjusted to give an output of about 16 volts. In the last position of SW2, both Q2 and Q3 are off and the total resistance is (PI + P2 + P3). P3 is now adjusted to give an output of about 27 volts.

Setting the three output voltages so that the motor locks reliably at each speed is quite critical. consequently all three potentiometers P1, P2 and P3 should be of the multi-turn type.

Finally, a clean mains clock signal with an exact 50 percent duty cycle is achieved by connecting the full-wave rectified but unsmoothed output of the bridge (at twice the mains frequency) to IC5, an LM 741 op-amp, configured as a comparator. The output of this chip is then divided by 2 in 1C6, another 4040.

The two frequencies from the divided tach and from the clock are compared in Gate N4 which switches the mosfet Q1. This in turn provides the motor with a pulse-width modulated drive, the width of the pulse varying as the loading on the motor changes.

Diode DI is connected directly across the motor and protects 71 by clamping to the positive rail the back EMF induced in the motor's windings every time it switches off. Diode D2 ensures that the momentary higher voltage on a charged C12 is blocked from the output of the LM 317 at the moment a slower tape speed is selected.

The rest of the circuit around the motor is intended to reduce as far as possible the switching noise that is produced by all circuits of this type.

Full circle

In developing this final circuit I have come full-circle in my thinking: I started with a defunct capstan motor which was mains-locked to 60 Hz and although my original intention was to get away from a synchronous motor, I have ended up with its DC equivalent.

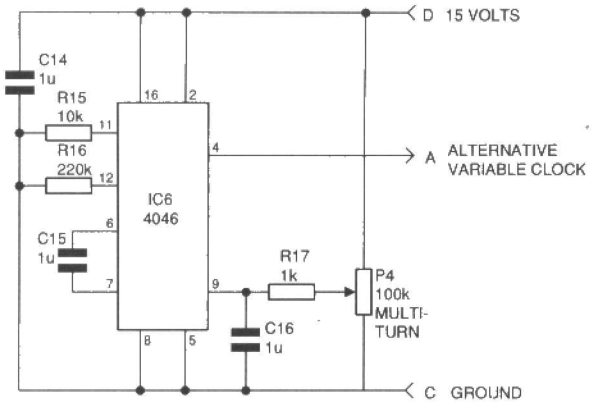


Figure 4: the circuit of a variable clock

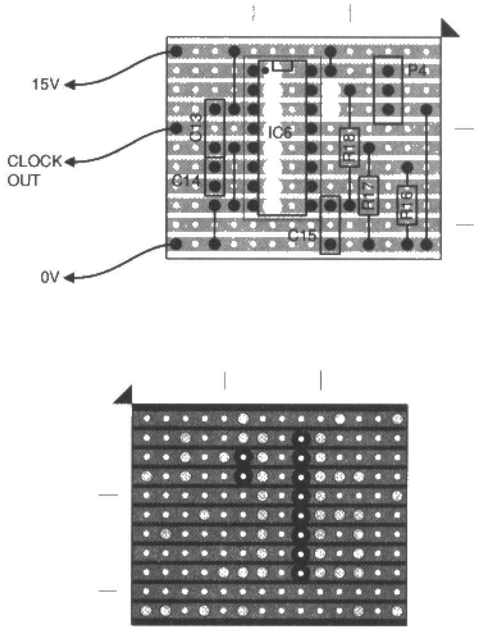


Figure 4a: building the variable clock on Veroboard

The major differences are the strong mains lock (hence a speed constancy of a very high order) and the torque potential of the motor in the circuit above. Both of these are much better than those of the tape-recorder's original motor. In addition, three tape speeds (or indeed more) are available with my version as against one in the original.

So having radically changed some of my early ideas, let me offer another small additional circuit which I intend to include in my tape-recorder, and which could be of interest to experimenters who may also want to use this circuit for other purposes.

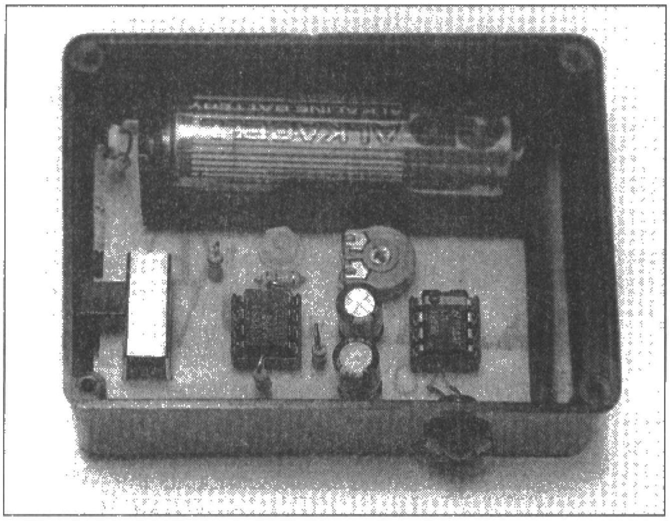
Figure four shows a circuit which can replace the mains frequency as the standard clock.

Using the CMOS 4046 chip and a few additional components, it is possible to make a variable standard. The output from Pin 4 is a clean, 50 percent duty-cycle square-wave whose frequency can be varied from about 30Hz to about 120Hz, (when the wiper of P4 will be joined to the 15 volt rail).

When this output frequency is initially set to about 50Hz and is connected to Pin 12 of Gate 3 in figure two, the motor will lock to it. Its speed will then track the varying frequency as P4 is adjusted. This results in reasonably stable and constant speeds from about 800 to about 1100 rpm for the speed setting of 3.75 ips. It will give proportional speed variations at the other settings.

Such a simple clock is not really good enough for normal use in a quality tape recorder, but it does allow the production of some interesting sound effects and will help in the re-recording of those irreplaceable cassettes and tapes which were made in some other machine whose batteries were running down.

I hope that some of the ideas and circuits I have described in these articles will be of use to other experimenters, and I also hope that describing the mistakes I made in my early experiments will save others the time I spent in pursuing what turned out to be blind alleys.



Mock alarm flasher

Keep thieves of balance with this handy fake alarm by Terry Balbirnie

Car owners beware! One-quarter of all crime in the UK is directed at cars - either theft of the vehicle itself or of articles left inside. If you own an expensive model, or a popular one which can be readily sold on by a thief, then fitting a good quality alarm and immobiliser is definitely advised. If you live in a relatively low-crime area, your car does not fit into the above categories and you are careful not to leave valuable belongings lying around, this circuit could be a useful low-cost alternative for you.

Only make believe

The Mock Alarm Flasher circuit provides a reasonable level of protection by making a potential thief think that you have a car alarm fitted even when you don't. It does this by making a red LED, mounted on the dashboard, flash like the one supplied with a real alarm. Of course, by using this device, there is no guarantee that the thief will leave your car alone. It does seem, however, that he is more likely to try his luck with another one where there appears to be no alarm.

Keeping up appearances

To deceive the criminal, any anti-theft device must look good. An LED hooked up to the cigarette lighter socket through a tatty piece of wire is a certain give-away. Not only does this circuit have a good appearance, but it will look unfamiliar. This means that the experienced thief, who knows the details of most commercial alarms, will be confused by this one and is more likely to leave the car alone. He has no idea how it might operate or whether there is an immobiliser involved. Anyone with access to a colour printer could enhance the deception by designing a professional-looking warning sticker to go on one of the windows.

The circuit is unusual because the power supply is a single AA size alkaline cell. This avoids having to make connections to the car electrical system. Also, because the unit is self-contained it may be moved from one vehicle to another in a matter of seconds. The unit is light enough to be held in position under the dashboard using two Velcro fixing pads. While driving along, the unit will be removed and placed out of the way. This is because, in the prototype, it was not considered worthwhile fitting an on-off switch on account of the extremely small operating current. If left in place, the flashing LED would be a dangerous distraction especially at night. Of course, such a switch could be fitted if desired, and this might be a good idea if the car is to be left standing for long periods in a locked garage. An on-off switch would also be needed if it was decided to mount the unit permanently in position.

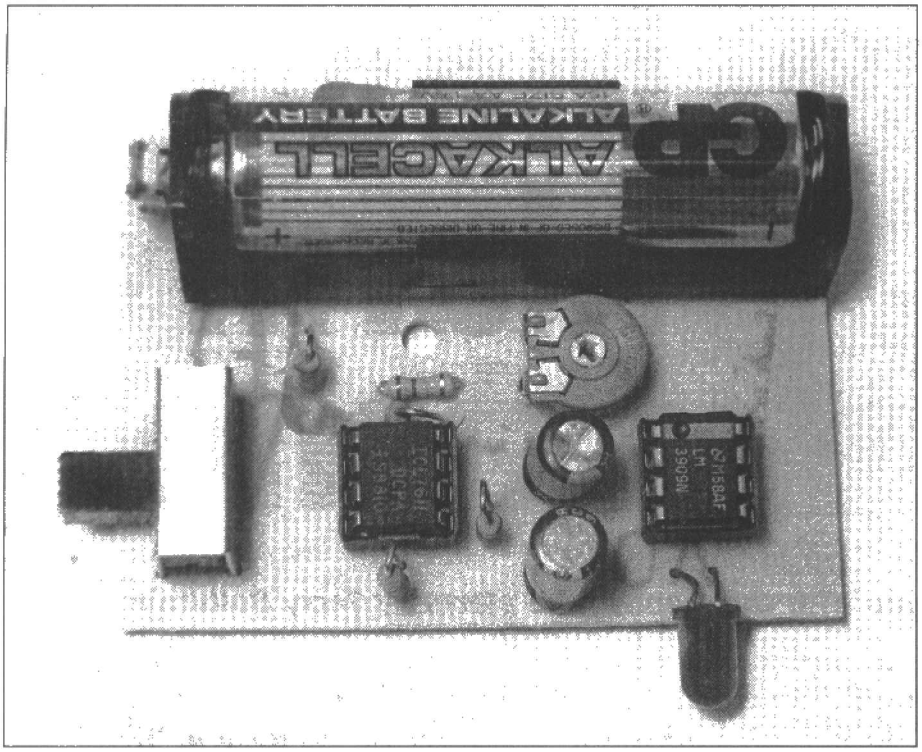
The cell should last for between 4 months and 1 year approximately depending on the circumstances of use. The lower figure will be applicable if the unit is left operating continuously. The higher one will apply if the circuit is used mainly in automatic mode (more will be said about this presently). The LED receives pulses of about 45mA which exceeds the maximum permitted continuous current and therefore produces maximum brightness. The LED is not damaged because of the very short on times. In fact, the average current is only 300uA (0.3mA) approximately.

Selector switch

To minimise the current requirement, the circuit has an alternative automatic mode. A switch on the side of the unit is used to select either "automatic" or "continuous" operation as required. In automatic mode, the LED will only operate when the ambient light has fallen below a certain preset level. It will therefore "arm" itself automatically at night. While under daylight conditions, and with the LED not flashing, the current requirement of the prototype is only 3uA which may be regarded as negligible. In areas where much of the vehicle crime takes place during the day, the device should be switched to "continuous" although it is arguable whether the thief will notice the LED as he would at night.

The light sensor used for automatic operation is mounted on the PCB with light reaching it through a small hole in the side of the case. There is no need for this to face a window - it will pick up sufficient illumination from its position under the dashboard. The light level at which the unit operates is adjustable and will be set at the end of construction.

Readers will no doubt find alternative uses for this circuit. It could be used to locate any item which needs to be found



in the dark such as a hand lamp. Boat owners and anglers will no doubt find applications for it. Anyone wanting to reduce the size of the unit could use an "N" size cell or possibly one of the larger silver oxide batteries. There will, of course, be a consequent reduction in life.

Little problem

There is a fundamental problem in making an LED work from a 1.5V supply. This is because it requires 2V approximately before it will conduct! Making such a circuit operate from a single cell therefore seems to be impossible. However, with a little ingenuity, an LED can be made to flash using such a low voltage. The spin-off is that a flashing LED will attract attention more effectively than one which glows steadily. It also uses much less power because it can be arranged to be off for most of the time. The basis of such a circuit is a capacitor. If one of these were to be connected across a 1.5V cell for a short time then removed, the voltage of the cell would exist across it. If the capacitor were now connected in series with the cell in the correct sense, double the supply voltage (that is, the voltage across the capacitor plus that of the cell) would appear across the pair. Since this is now a 3V supply, it would be sufficient to operate an LED It would therefore light until the voltage across the capacitor fell below 0.5V (that is, the voltage across the pair reaching 2V). This method would work until the voltage of the cell fell below 1V which is usually regarded as the useful end-point anyway.

The LED could be made to emit a series of flashes by repeating the procedure above. Obviously, it would be impractical to do this manually but there is an ic which is designed for the purpose. This consists of an oscillator (pulse generator) which operates by repeatedly charging and discharging a capacitor through internal circuitry. The internal details of this ic are actually quite complicated and no detailed explanation will be given here. It is sufficient to say that the capacitor used for the oscillator is also used to provide the voltage doubling effect. The end result is a series of short pulses of double battery voltage which are applied to the LED

Circuit description

Figure 1 shows the complete circuit for the Mock Alarm Flasher. The integrated circuit LED flasher is IC2. Disregard IC1 and associated components for the moment (this is the light-sensing section) and imagine IC2 pin 5 (supply input) is at positive supply voltage (nominally 1.5V). Capacitor C2 connected between pins 1 and 8 on one hand and pin 2 on the other performs the

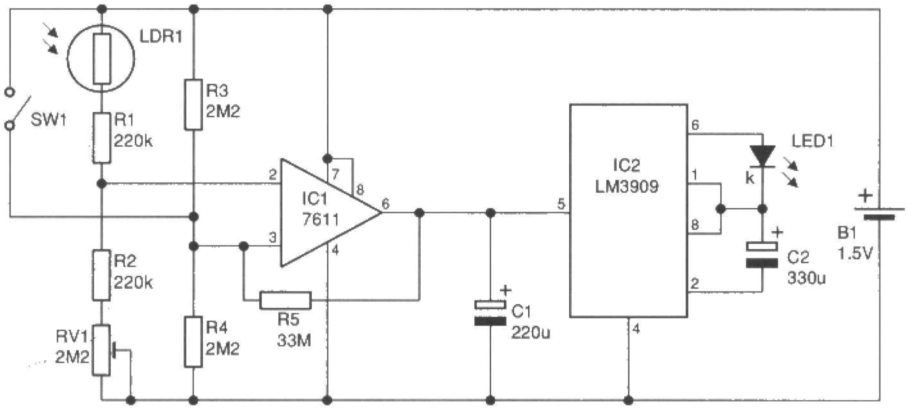


Figure 1: the circuit of the Mock Flasher

oscillator/voltage doubling functions referred to above. LED1 is connected between pin 6 (anode) and 1 and 8 (cathode). Note that no conventional series resistor is needed here since current-limiting takes place on the chip. In the prototype it was found that much better results were obtained by using a high brightness LED.

The light sensor section operates in the following way. Operational amplifier IC1 is of a type chosen specially for its extremely small current requirement. Also, it will also work down to a supply voltage of 1V which is important for this application. The sensor itself consists of a miniature light-dependent resistor, LDR1. Note that the specified component could be replaced directly with a standard ORP12 type but more space would be needed inside the case. An LDR has a resistance which depends on the amount of light falling on its sensitive surface - as the light level rises, the resistance falls. When it is placed in near-dark conditions, it will have a resistance of 1MW or more. In position under the dashboard of the car and with light reaching it through a small hole, it will have a resistance of a few thousand ohms.

Potential divider

The LDR is connected in series with a fixed resistor, R1, and this forms the top arm of a potential divider. The lower arm comprises resistor R2 and preset potentiometer RV1 connected as a variable resistor. The mid-point of the potential divider is connected to the inverting (-) input (pin 2) of the op-amp. Thus, as the light level reaching the LDR is reduced, the voltage at pin 2 will fall. The non-inverting (+) input, pin 3, receives a fixed voltage equal to one-half that of the supply (nominally 0.75V) due to the potential divider consisting of equal-value resistors, R3 and R4. With suitable adjustment to RV1, the voltage at the inverting input will be greater than that at the non-inverting one during daylight hours but will fall below it at night. When this happens, the op-amp switches on and its output becomes high. This provides a power supply to IC2 pin 5.

The exact level of illumination at which the device switches on will be set by means of RV1 at the end of construction. The operating point will not change as the battery ages. This is because the voltages at both op-amp inputs are derived from potential dividers connected across the supply. Thus, as the supply voltage falls, both voltages will fall in sympathy and the relative conditions will be the same. R5, introduces a small amount of positive feedback which sharpens the switching action.

For reasons which will not be entered into here, the operating current of the op-amp is programmable. By inter-connecting pins 7 and 8, it is set to require the minimum current - only a few microamps. Minimising the current is desirable in the interests of long battery life. Note also that all resistors in the potential dividers have very high values which, again, reduces the standing current. Even if the LDR is placed in bright light and RV1 is adjusted to a low value, the current will be limited by resistors R1 and R2 to 3uA approximately.

Energy reserve

With IC2 pin 5 high, the LED flashes. Since relatively high-current pulses are provided by pin 6, the input current will similarly pulse. To obtain this correctly using the specified op-amp, it is necessary to provide a reserve of charge using capacitor C1. This charges up while the LED is off and helps to provide the current for each flash.

With the component values used here, the flash rate is about once per second with a fresh battery but this will fall somewhat with the voltage of the cell. With a supply of 1V, the flash rate will be roughly once every two seconds.

When the contacts of switch SW1 are open, the circuit will operate as described above when the light level is sufficiently small. However, by closing the contacts it will operates in continuous mode. This is because resistor R3 is now bypassed and this makes IC1 pin 3 (non-inverting input) high. It will therefore exceed the voltage at the inverting input (pin 2) whatever that voltage might be. The op-amp will therefore switch on and a supply to IC2 established. To switch the circuit off completely, possibly because the unit is not going to be used for several weeks, it might be worthwhile removing the battery. Alternatively, the negative track from the battery holder could be broken at the PCB and a small switch connected between the ends.

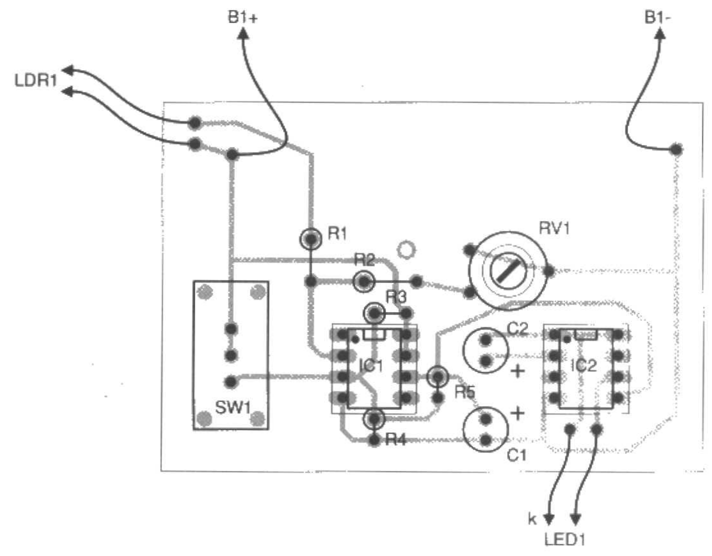


Figure 2: the component layout of the Mock Flasher

Construction

It will be noted that everything, including the cell holder and switch, are mounted on the PCB. Begin by drilling the mounting hole and soldering the cell holder, switch and two ic sockets in position. The cell holder must be mounted with the negative end (having the spring connection) to the right. Note that the switch is of the right-angled type, and the tags at the corners are for mounting purposes only. Solder the resistors, including the preset, in position. Note that resistor R5 has a very high value, and this may not be readily available. If necessary, use three 10M units connected in series, zigzag fashion, instead. There is sufficient space between IC1 and the capacitors to accommodate them. Note that both capacitors are electrolytics and must be connected the right way round. The negative end is clearly marked. Solder LDR1 in position. Be careful: this component is easily damaged by excessive heat from the soldering iron. To avoid this, push the end wires through the holes so that it stands about 10mm above the PCB. Solder each lead while gripping it with fine-nose pliers between the LDR body and the PCB. This will provide a simple heat shunt and prevent excessive heat conducting along the wires to the device. Bend the leads gently so that the "window" points to the side. Bend the LED leads through right-angles close to the body. Solder them so that the device stands a few millimetres above the PCB again, taking care over the polarity.

Making your mark

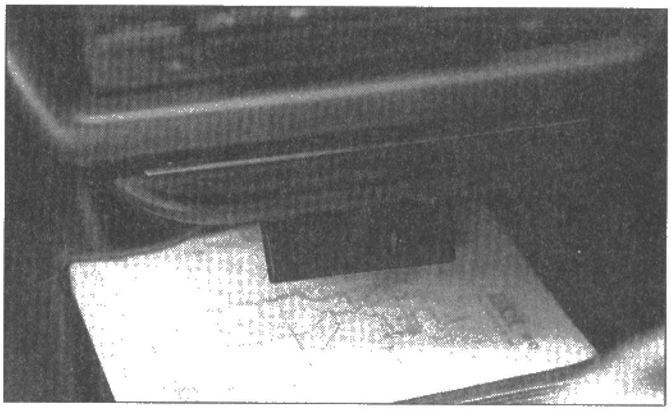
Measure the positions of the switch, LED and LDR on the PCB. Make holes in the box to correspond with these. Allow for the switch lever to protrude through its hole only by a small amount. It will spoil the appearance and the project will look amateurish if it protrudes too far. The hole for the LDR should be drilled to a diameter of 4mm approximately. The hole for the LED should be large enough for the clip. By a process of trial and error, file the switch hole to the correct size so that it can be operated easily. Bend the LDR leads so that the body lies about 5mm behind the hole. Insert the LED clip into its hole. In the prototype, it was found convenient to reduce the length of the clip slightly to provide more space. Place the PCB in its correct position and engage the LED with the clip bending the leads as necessary. When satisfied about the position, mark the case through the fixing hole. Drill this hole, then mount the PCB using a countersunk bolt with the nut on the inside of the box. Check that the switch can be operated easily and make adjustments as necessary. Measure the position of RV1 and drill a hole in the lid to correspond with its centre. This should be large enough to accept a small screwdriver or trimming tool so that the operating brightness level may be adjusted when the lid of the case is on. Adjust the preset to approximately two-thirds of its total clockwise rotation and switch SW1 on (for continuous operation).

Checking it out

Testing is simply a matter of checking that the circuit operates correctly. Insert a new AA cell into the holder and attach the lid of the case. The LED should begin flashing at about once per second.

Test the automatic feature by switching SW1 off. Providing there is sufficient light reaching the LDR the LED will not flash. Cover the hole with a finger and note that flashing resumes. If this does not work, adjust RV1 and try again. It will be necessary to adjust RV1 for correct operation when the device has been attached in position under the dashboard. Note, however, that it should be adjusted to at least one half of its total clockwise rotation or "continuous" operation may be rather dim and slow.

Chose a suitable position for the unit. The LED must be clearly visible to any potential thief. In the prototype, Velcro fixing pads were used to hold the box in position. Make sure that the LDR receives some light even though this does not need to be bright. If too much light enters the hole, the circuit may not work properly. It may then be necessary to restrict the amount of light entering by partially covering the hole with black pvc tape. Note that, once working, the light will need to become a little brighter for it to switch off again - such is the action of the positive feedback applied to the op-amp. If this effect is too great, the value of resistor R5 should be increased. The cell should be replaced when the flashes become dim.



PARTS LIST for the Mock Flasher

Resistors

R1, R2	220k
R3, R4	2M2
R5	33M or 3 x 10M - see text
LDR1	Miniature LDR with dark resistance of 1MW or more
RV1	2M2 min horiz preset

Capacitors

C1	220u 6.3V
C2	330u 6.3V

Semiconductors

IC	ICL7611
IC2	LM3909
LED1	5mm red high brightness LED

Miscellaneous

SW1	Miniature PCB mounting right-angled SPDT slide switch

B1 AA size alkaline cell and PCB mounting cell holder; PCB; 2 x 8-pin dil sockets; clip for LED plastic box size: 75 x 56 x 25 mm approximately; small fixings.

The correct value resistor for R5 may be obtained from Maplin as a "high voltage" resistor (order code V33M) or from Electromail as a cermet film resistor order code: 158-187. Alternatively, three 10M resistors may be connected in series to provide the near-correct value. The LDR was Maplin order code AZ83E. Alternatively, the widely-available ORP12 type could be used but a larger box would probably be needed. IC2 (LED flasher) is available from Maplin order code WQ39N or Electromail order code 300-372.

SPICED CIRCUITS

Circuit simulation with software, by Owen Bishop. This month, part 4 - Going digital.

Before we turn to digital circuits we look at last month's problems. Circuit (a) really was a bad one, as its DC quiescent analyses made plain. A DC voltage analysis shows Vout = 7.33V. To allow maximum amplification the quiescent output must lie about midway between positive and negative rails, around 4.5V. Vout is far too high. The next step is to check the quiescent currents. Is any component on the point of melting? A simulator does not produce the 'expensive smell of burning' which, on a real circuit, warns us that something is amiss. Under Probe nodes, set a probe to measure current (it does not matter which component you select), and DC Quiescent will then display branch currents instead of node voltages. The resulting table shows that there is no current likely to destroy the components but a collector current of 42.8mA is unnecessarily high. Finally, try a Transient analysis of Vout at, say, 1kHz (figure 1). This was a pure sine wave before it went through the amplifier, but now is quite different. And, speaking of amplification, the input signal has 1V amplitude but the amplitude of the output signal is only 0.364V. Distortion and signal attenuation combined make this a bad amplifier. What can we do about it?

If we decide on 2mA as a suitable collector current, and require a drop of 4.5V across R1 to place the quiescent signal midway between the power rails, the value of R1 should be about 4.5V/2mA = 2250 ohms. Replacing 39 ohms with 2.2 kilohms alters voltages elsewhere in the circuit but the final value of R1should be somewhere in this region. If this was a breadboarded circuit, we might put a 25k pot in place of R1 and rotate it through its range while measuring the collector voltage with a multimeter. In this simulator we do a similar thing by sweeping R1 from 1k to 2.5k and plotting a Quiescent sweep of Vout (figure 2). We are also plotting the current through R1, but multiply the result by 1000 before plotting, to bring it on to the same scale. The two are proportional so the curves are parallel. The cross-hairs show Vout = 4.5V when N=13.319. N is a hypothetical sample number based on a total sample of 100. In Tolerances and Temp, to save time, we took only five samples. To convert N to an actual resistor value, calculate:

v = Start + N/100 x Range

Here Start = 1 kilohm and range = 1.5 kilohm so, in kilohm, v = 1 + 13.319/100 ◊ 1.5 = 1.2 kilohm. This would be a suitable value for R1 were it not for the fact that the corresponding current is 3.8mA. Obviously the transistor is saturated or nearly so; we must reduce the base current. The BC548 is a high-gain transistor; gain is quoted in various tables as 'less than 520 at 2mA' and '110 to 800'. Since we are using a Spice model (supplied by Zetex Plc), we can Explode the netlist and look for the value of BF, the forward voltage gain, which is seen to be 400. If collector current is to be 2mA, then base current should be 2mA/400 = 5uA. If R3 = 1k and emitter current is (very close to) 2mA, emitter voltage is 2V. Base voltage should be 2 + 0.6 = 2.6V. The drop across R2 is to be 4.5 -2.6 = 1.9V and (with 5uA of current), R2 = 1.9/5uA = 380 kilohm. Make it 390k, then repeat the Quiescent sweep. Now we have to increase the

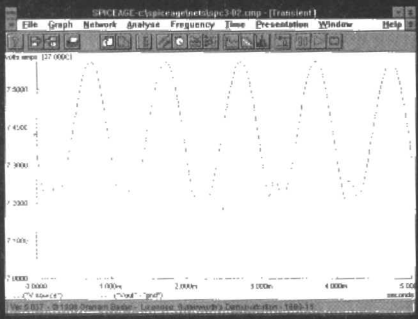

SPICEAGE-c:\spiceage\nets\spc3-02.cmp - [Transient]
File Graph Network Analyse Frequency Time Presentation Window Help
volts amps [27.000C]
7.5000
7.4500
7.3000
7.2000
7.1000
7.0000
0.0000
1.000m
2.000m
3.000m
4.000m
5.00
seconds
("Vout" - "gnd")

Figure 1: the output from last month's problem amplifier. The signal began as a pure 1kHz sine wave, amplitude 1V

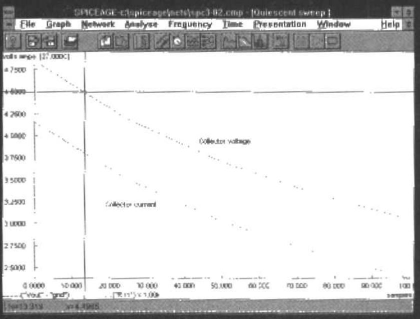


Figure 2: a Quiescent sweep shows how Vout and the collector current vary as R1 is swept from 1k to 2.5k

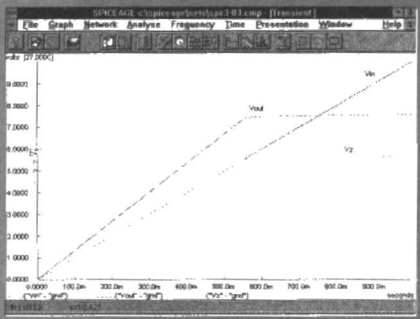

SPICEAGE c:\spiceage\ports\spc3-03.cmp - [Transient]
File Graph Network Analyse Frequency Time Presentation Window Help
Volts [27.000C]
9.0000
8.0000
7.0000
6.0000
5.0000
4.0000
3.0000
2.0000
1.0000
0.0000
Vin
Vout
Vz
0.0000 100.0m 200.0m 300.0m 400.0m 500.0m 600.0m 700.0m 800.0m 900.0m
seconds
("Vin" - "gnd") ("Vout" - "gnd") ("Vz" - "gnd")

Figure 3: voltage levels in the precision voltage regulator as Vin is swept up from zero to 10V

range from 1k to 3k to get a collector voltage at 4.5V and, when we do, we find that the required value for R1 must be 2.66k. Make it 2.7k and try a Transient analysis to see how well the amplifier works now. The result shows a signal gain 2.6, centred on 4.5V, but still bottoming out as in figure 1. Better, but not good enough. Readers may have already spotted the deliberate mistake, the omission of a by-pass capacitor across the whole or part of R3. Feedback is limiting the gain. After adding a 100u by-pass capacitor to the netlist and reducing the signal amplitude to 500uV, we obtain what looks like a pure sine wave output, amplitude 75.5mV (gain 155). A Fourier analysis checks that this is reasonably pure.

We could continue with improvements, tweaking the values and possibly by-passing only part of R3 to obtain even better performance. Now we must look at the second of last month's problems, the precision voltage regulator. It can be shown that Vout = Vz ◊ (R2 + R3)/R3, and this is seen to be true in figure 3, in which Vin is ramped up from zero at 10V per second. We are mainly interested to know how Vout responds to variations in load, and in supply voltage. Set up the circuit with Vin = 8V, a load resistor R4, sweep its value from, say, 10 ohms to 1 megohm and watch its output voltage as you do a Quiescent sweep (see above). For such a wide sweep it is best to select a log scale. The result shows output to be within a few percent of the expected 7.55V if the load resistor in 1 kilohm or more. To narrow down the lowest acceptable value, set the range from 1k to 5k and find that Vout rises to within 1 percent of 7.55V provided the load resistor exceeds 1.4k.

To investigate the effects of supply voltage, replace B1 and B2 by two voltage sources, ramped up from 0 to 30V at 10V per second and run the simulation for 3 seconds. The graph shows that Vout is close to Vsupply for values below 7.55V. At supply voltages above 7.55V, Vout is steady at 7.55V up to 30V and possibly beyond. The current through the Zener remains constant at 4.2mA, close to the recommended level of 5mA.

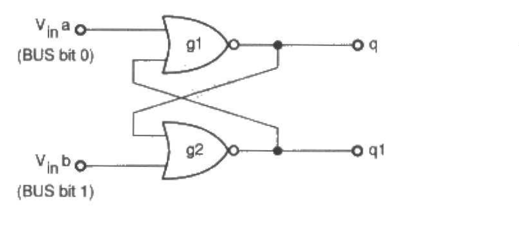


Figure 4: a set-reset flip-flop made from cross-connected NOR gates

Logic

Now to consign the resistors and op amps to the spares box and get out the logic ics. Put away the oscilloscope and switch on the logic analyser. Spice does not have logic gates among its primitives, which is not surprising since one of the purposes of Spice was to assist the designing of integrated circuits, including logic circuits, from on-chip resistors, capacitors and semiconductors. Nevertheless, many users of computer simulators want to be able to include logic in their circuits. Some simulators are specialised for logic, and some use different techniques for analysing the logical and the analogue parts of circuit. Other simulators, including SpiceAge, have what is known as mixed mode analysis. This allows digital and analogue devices to be connected in all manner of combinations (provided they are workable in the electronic sense) and the circuit is analyses as a whole. Logical gates are treated in the same way as analogue circuits. This approach is essential for mixed-mode circuits but has the disadvantage that it is not ideal for purely logical circuits. Logic circuits tend to remain in the same state for relatively long periods and change state rapidly at infrequent intervals. For most of the time nothing significant is happening. It is a waste of computing resources to process circuit states repeatedly and get the same answer every time until something changes. This disadvantage is offset in SpiceAge, which has a mode of operation known as optimising, in which the intervals between sampling times are extended when there are no changes to voltages or currents in the circuit. The analysis skips ahead to the next occasion on which something interesting starts to happen. Then the sampling intervals are shortened to allow the changes to be computed accurately. Even so, the analysis of a logical circuit such as an 8-bit shift register built up from individual gates and latches can take a long time.

As an example of the technique, consider an often-used memory unit, a flip-flop built from two cross-connected NOR gates (figure 4). The NOR gate is already defined as a library file and the netlist of figure 4 calls it twice:

```
*   NOR flip-flop
B   b1   +out:pos -out:GND  v=5.000000
BUS     input  ff1.genp1:gndp2:Vina p3:Vinb   v=5.000000
>   g1  NOR  a:Vina  b:q/     out:q   VDD:posgnd:GND
>   g2  NOR  a:q      b:Vinb  out:q/  VDD:posgnd:GND
```

The battery (B) is needed to power the gates. The input of logical devices can be driven by ordinary voltage generators such as we have used already, but it is usually more convenient to employ a BUS generator. This is programmed to output a sequence of logical highs and lows by setting up a .GEN file. Here is a .GEN file (called ff1.gen) suitable for demonstrating the action of the flip-flop:

```
0 #10
10n #00
10u #01
20u #00
30u #01
40u #00
50u #10
60u #00
<REPEAT>
```

ETI
ELECTRONICS
TODAY INTERNATIONAL

PCB Service

ETI can supply printed circuit boards for most of our current projects - see the list below for boards available. For recent boards not listed, check the constructional article for an alternative supplier.

Please use this order form or a copy of it. Check that all relevant information is filled in, including the Unit Order Code, and that you have signed the form if sending a credit card number. Overseas customers please add postage appropriate to the number of units you are ordering. Make cheques/POs/money orders, in £ sterling only, payable to Nexus Special Interest Limited. Please allow 28 days for delivery. Access/Visa orders may be made on 01442 66551 (ask for Readers Services).

Only boards listed here are available from our PCB Service. For past issues of magazines, copy articles or binders, please see the admin panel (page 74) or contact Readers Services (see below) for information.

Name and issue of project	Unit code	Price
ETI Issue 10 1997		
The IQ Tester	E/1097/1	£5.64
Fake Flasher	E/1097/2	£5.09
DC Motors (Part 2)	E/1097/3	£6.77
Valve Tester - Main Board	E/1097/4	£21.22
Valve Tester - Socket Board	E/1097/5	£5.09
Valve Tester - Heater Regulator	E/1097/6	£5.09
All three Valve Tester boards	E/1097/4/5/6	£30.30
(Due to price breaks there is a small discount on this item.)		
ETI Issue 9 1997		
Eprom Emulator	E/997/1	£16.49
The Power Supply	E/997/2	£5.09
Electronic Door Chimes	E/997/3	£5.09
Digital Power Supply	E/997/4	£10.11
ETI Issue 8 1997		
The Brake Light Tester	E/897/1	£5.09
The IQ Tester	E/897/2	£5.64
DC Motors (3 experimental boards)		
DC Motors: The first Control Unit	E/897/3	£5.09
DC Motors: The 4046 Circuit	E/897/4	£5.09
DC Motors: The Crystal Drive Circuit	E/897/5	£5.09
All three DC Motors boards	E/897/3/4/5	£11.50
ETI Issue 7 1997		
Eprommer: main board (double sided)	E797/1	£13.32
Eprommer: PSU board	E797/2	£5.64
Eprommer: personality modules (double sided):	E797/3	
Any ONE module board		£5.09
Any two modules		£7.90
Any three modules		£11.85
Any four modules		£15.80
Any five modules		£19.75
All six modules		£23.70
Please specify which Eprom modules you require. Modules are for 2716, 2732, 2764, 27128, 27256 or 27512. One order code/overseas postal charge applies whether a selection or all six personality module boards are ordered.		
Are Your Lights On?	E/797/4	£5.09
Peak Reading VU Meter	E/797/5	£5.09

Terms of trade

Terms strictly payment with order. We cannot supply credit orders, but will supply a proforma invoice if requested. Proforma orders will not be processed until payment is received. All boards are manufactured from the foils that appear in the ETI Foils Pages for the appropriate issue. Please check that our foils are suitable for the component packages you intend to use before ordering as we cannot supply modified boards or replace boards that have been modified or soldered. Boards are only supplied in the listed units. Sorry, we cannot break units. Prices and stock may be altered without prior notice. Prices and stock listed in this issue supersede prices and stock appearing in any previous issue. ETI, Nexus Special Interests and their representatives shall not be liable for any loss or damage suffered howsoever arising out of or in connection with the supply of printed circuit boards or other goods or services by ETI, Nexus Special Interests or their representatives other than to supply goods or services offered or refund the purchaser any money paid in respect of goods not supplied.

Please supply:

Quantity	Project	Unit Order Code	Price	Total price

Prices are inclusive of post and packing in the UK. Overseas Post and Packing (if applicable): Add £1 per unit

Name ....
....

Address ....
....
....
....

I enclose payment of £ .... (cheque/PO/money order in £ Sterling only) to:

PCB Service, READERS SERVICES DEPARTMENT, Nexus Special Interests Ltd.,
Nexus House, Boundary Way, Hemel Hempstead, Herts HP2 7ST UK.

or charge my credit card number

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Signature: ....

Card expiry date: ....

It consists simply of a 2-column list of times and logic levels, the '#' indicating that we are using binary values. This example has only a 2-bit output (bit 1: bit 0) but BUS generators can produce up to 8 bits. Although the file is made to repeat, it is really intended for a single run. It begins with a short (10ns) high pulses on bit 1. This is just a preliminary to the sequence, intended to kick the flip-flop to flip or flop into one of its stable states. If we begin with #00, the simulator can not find either state, since the gates (unlike real on-chip gates) are identical. This is a problem with all symmetrical oscillating circuits, especially those like figure 4 which have feedback. The simulated components are too perfect!

We could display the results as a set of superimposed graphs in the usual way, but SpiceAge has a logic probe display which plots logic levels separately instead of on one set of co-ordinates (figure 5). Here we see the initial kick on Vinb, initialising the flip-flop with q high and q/ (q-bar) low. Then follows a 10us period with both inputs low, the normal 'resting' situation. At 10us a high pulse on Vina sets the flip-flop to make q low and q/ high. A second high pulse on the same line has no effect, but a high pulse on the other line makes the flip-flop revert to its original state.

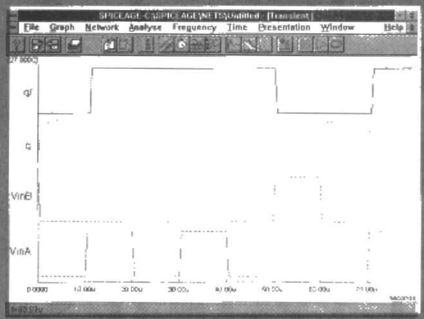

SPICEAGE-C:\SPICEAGE\NETS\Untitled - [Transient]
File Graph Network Analyse Frequency Time Presentation Window Help
q/
q
VinB
VinA
0.0000
10.00u
20.00u
30.00u
40.00u
50.00u
60.00u
70.00u
seconds

Figure 5: putting the flip-flop through its paces

Counters

All the elementary logic functions (NOT, AND, OR, NAND, exclusive-OR, ...) are available as ready-made library files. These in turn can be built up into more complicated D-type and JK-type flip-flops. Carrying this process further, these may be used to build counters, registers, and other medium-scale logic devices. Figure 6 is the circuit of a 2-stage binary ripple counter made from two J-K flip-flops. The flip-flops are library files (7472.lib) which simulate the 74HC ics with cmos circuitry:

```
* Ripple counter
B  b1   +out:pos   -out:GND   v=5.000000
Bus  clock   clock   p1:gnd   p2:a   p3:clear1   p4:clear2   v=5.000000
> jk1   7472   q\:b   k:pos   j:pos   ck:a   pr\:pos   clr\:clear1   +v:pos   gnd:GND
> jk2   7472   q\:c   k:pos   j:pos   ck:b   pr\:pos   clr\:clear2   +v:pos   gnd:GND
```

Figure 7 displays the output from the counter. Once again the flip-flops do not settle to a stable state after switch-on without some prompting. In this case we need to clear the flip-flop by making the CLEAR input low then making it high. It is the transition that clears it, not just applying a high level, and the clock input must be low when this is done. Arranging for this requires some thought; one way of doing it is shown in the .GEN file:

```
0 #000
10n #010
20n #011
2u #110
20u #111
40u #110
60u #111
80u #110
100u #111
120u #110
140u #111
160u #110
180u #111
200u #110
220u #111
240u #110
```

The three outputs are (R-to-L) clock (node a), clear1, clear2. Flip-flop 1 is cleared by a rising edge at 10ns, and q goes low but, since we are using q/ from flip-flop 1, we need a short clock pulse to set q high, making q/ low. This begins at 20ns and takes until 2us, when we can clear flip-flop 2 by making clear2 high. Both flip-flops are now reset, so nodes b and c are low. From 20us onward, the clock alternates between high and low, taking the system through binary counts 0 to 7, and repeating.

Problem

If we want to generate a short pulse at every fourth count (when b=0 and c=0), we can wire a 2-input NOR gate to nodes b and c and take the output from that gate. Try it on a simulator or breadboard. What goes wrong? What can be done to avoid it?

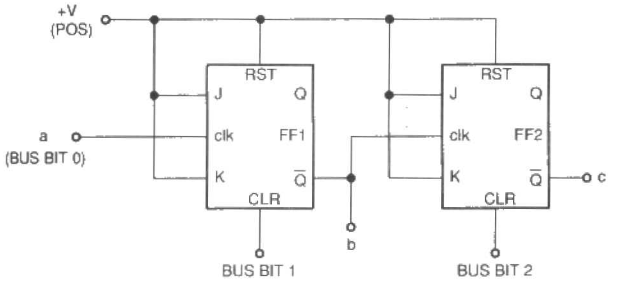


Figure 6: a binary counter built from two J-K flip-flops

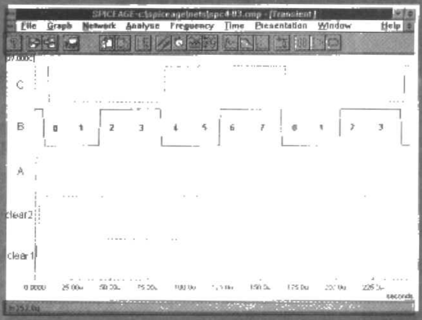
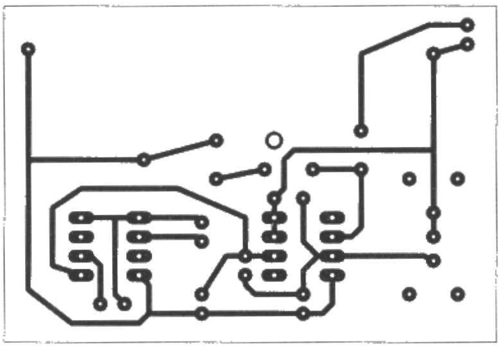
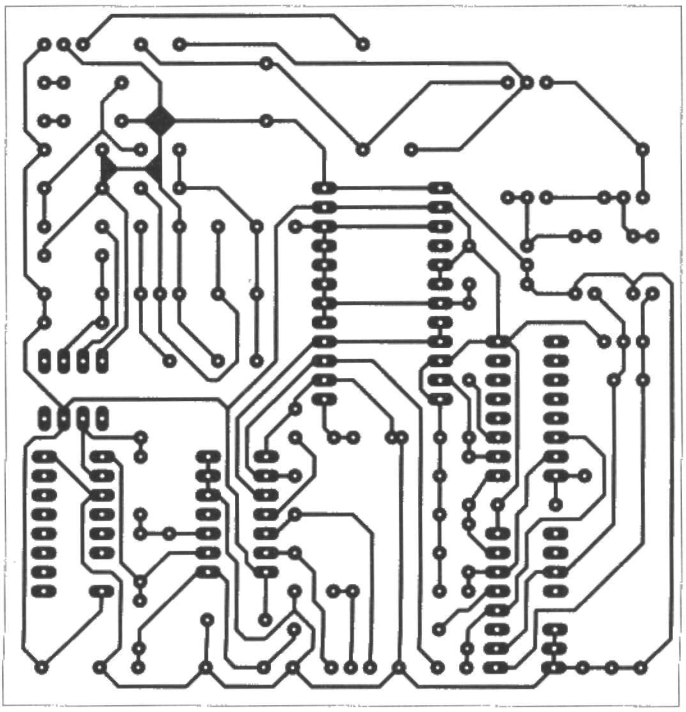

SPICEAGE-c:\spiceage\nets\spc4-83.cmp - [Transient]
File Graph Network Analyse Frequency Time Presentation Window Help
C
B
0 1 2 3 4 5 6 7 0 1 2 3
A
clear2
clear1
0.0000
25.00u
50.00u
75.00u
100.0u
125.0u
150.0u
175.0u
200.0u
225.0u
seconds

Figure 7: the output from figure 6

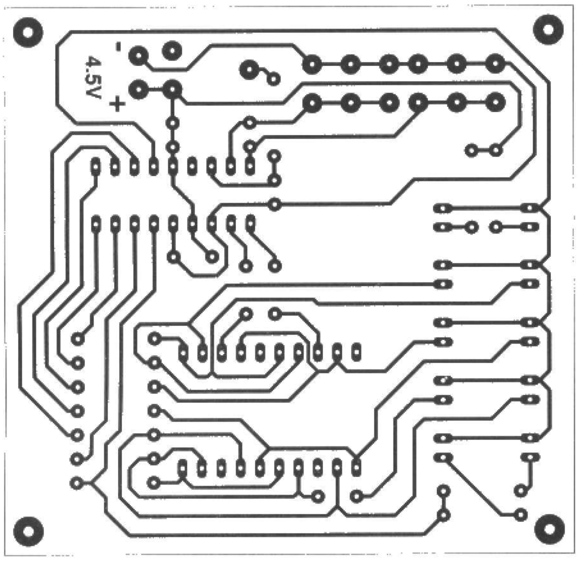
FOILS FOR THIS ISSUE



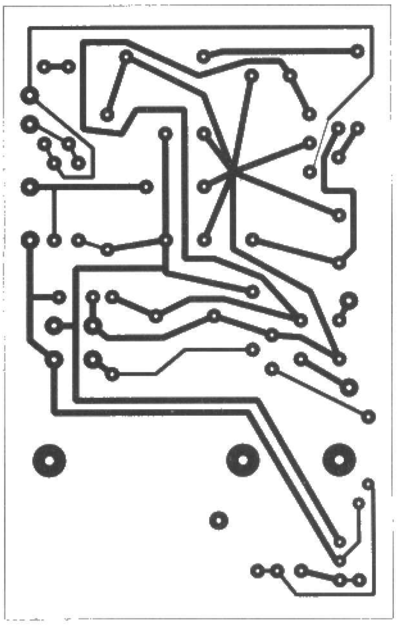
FAKE FLASHER



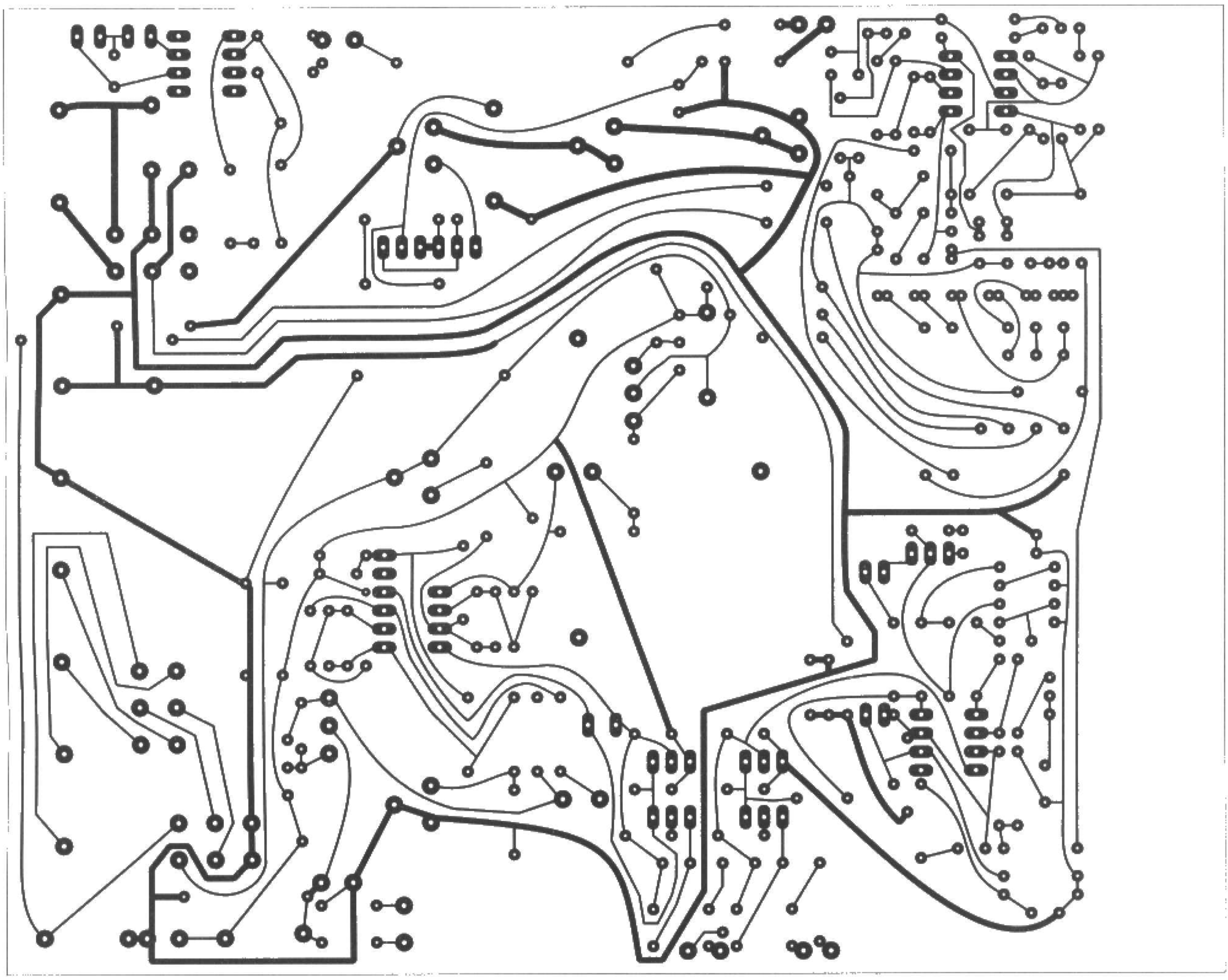
DC MOTORS



IQ TESTER

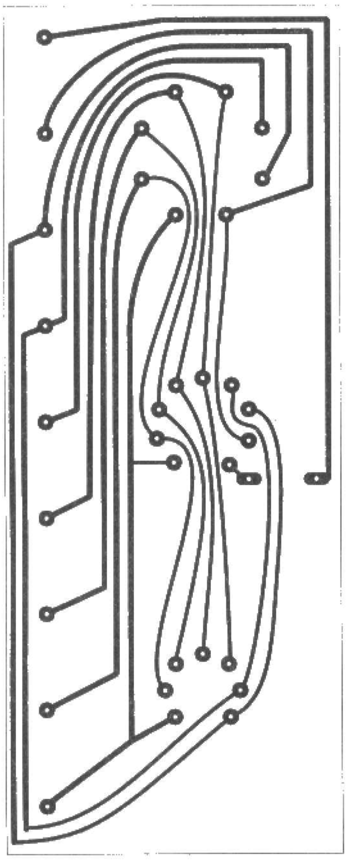


VALVE CHARACTERISTIC TESTER: HEATER



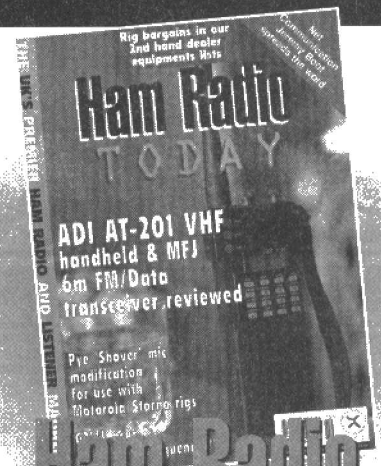
VALVE CHARACTERISTIC TESTER: MAIN BOARD

FOILS FOR THIS ISSUE



VALVE CHARACTERISTIC TESTER: SOCKET BOARD

Calling all Radio enthusiasts


Rig bargains in our 2nd hand dealer equipments lists
Ham Radio TODAY
THE UK'S PREMIER HAM RADIO AND LISTENER MAGAZINE
ADI AT-201 VHF handheld & MFJ 6m FM/Data transceiver reviewed
Pye 'Shaver' mic modification for use with Motorola Storno rigs

Ham Radio TODAY

The magazine for amateur radio

New equipment, scanners, packet radio, construction, club news, views and much more.

This month in HRT:

On Test: ASI AT-201 VHF Handheld
G4HCL finds that low cost doesn't compromise performance and features in his test of this budget 2m rig.

MFJ-9606 6m FM/Data transceiver
HRT's Tech Ed takes a look at a simple-to-use 6m rig for voice and packet.

Pye 'Shaver' microphone conversion
Mike Rowe G8JVE converts the Pye 'Shaver' microphone for use with Motorola/Storno ex-PMR rigs.

All In A Day's Work
Harry Leeming G3LLL asks "who's off frequency?" and shows how you can make sure it's not you!

Rig bargains
Our Second-Hand Dealer Equipment Lists - get your bargain here!

Software Offer
Another bumper selection of the latest low-cost Ham Radio PC software, a selection exclusive to Ham Radio Today readers.

PLUS

Radio Today, Scanners for listeners, great value radio Software Offers, free readers' ads, band reports and more.

OUT NOW!

All contents are currently planned, but may alter.

Ham Radio Today is published by Nexus Special Interests Ltd., Hemel Hempstead. UK Newstrade Distribution by Comag Magazine Marketing, Tavistock Road, West Drayton, Middlesex UB7 7QE. Tel. 01895 444055. Subscriptions/Back issues available from: Nexus Subscription Services, Tower House, Sovereign Park, Lathkill Street, Market Harborough, Leicestershire LE 16 9EF. Tel.01858 435344.

Practically Speaking

BY TERRY BALBIRNIE

This month we look at the use of light emitting diodes

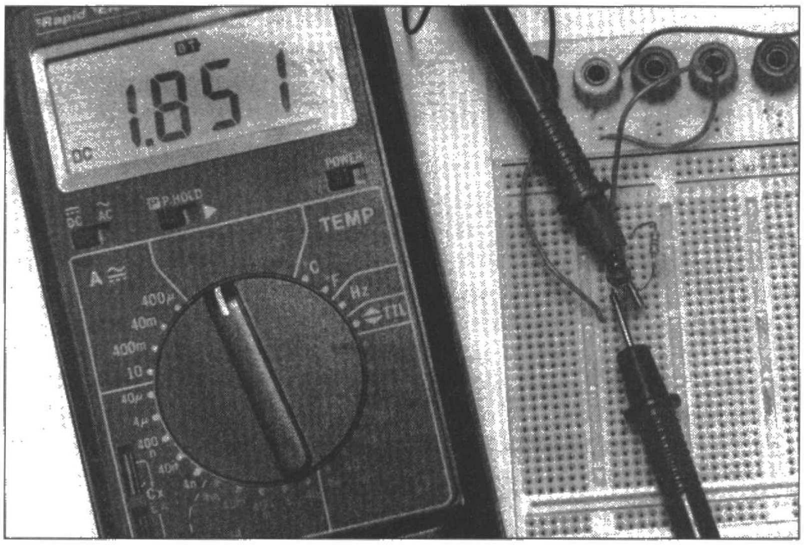
This month we continue looking at some of the calculations used when developing and testing electronic circuits. This part is devoted to the use of light-emitting diodes.

Better all round

A light-emitting diode (LED) is often used as an indicator light or status indicator. It has the advantage of needing a smaller current than a filament lamp, is generally smaller, remains cool in operation and is much more reliable. Moreover, it can be bought in various colours, shapes and sizes.

As a rule, a light-emitting diode must not be connected directly across the power supply. If it was, an excessive current would flow and it would be destroyed. A resistor must be connected in series with it to limit the current to a safe working value. There are one or two exceptions and these will be explained presently.

If the LED is red, orange, yellow or green (the most common colours) then, while operating, there will be between 1.8V and 2.2V across it. This is called the forward voltage drop. When calculating the value of the current-limiting resistor, this will need to be taken into account. For ease of calculation, it is usually taken to be 2V. You must first decide what operating current is to be used. With most LEDs, adequate brightness will be obtained with about 5mA to 25mA for a red one and between 10mA and 40mA for yellow, orange and green. The LED will be destroyed with much more current than this.



Measuring voltage across a resistor

Ohm's Law

For the sake of the following calculation, let us assume that the operating current is to be 15mA. You now need to know the voltage of the supply. Suppose it is 9V. There will therefore be (9 - 2)V or 7V appearing across the resistor. Since the resistor and the LED are in series, the same current will flow through each. Applying Ohm's Law, as discussed in our last installment, to find the value of the resistor, gives:

$$R = V/I = 7/0.015 = 467 \text{ ohms}$$

So, depending on the type of circuit, we round up or down to the nearest available value, say, 470 ohms.

If the supply voltage falls, as when the battery ages, you will need to check that an adequate current flows when this reaches its useful end point. Suppose it is 6V. The voltage across the resistor will now be only 4V. Ohm's Law is applied again, but this time to find the current using the resistor value decided on above:

$$I = V/R = 4/470 = 0.0085\text{A or } 8.5\text{mA}.$$

This would be satisfactory for a red LED but perhaps not for other colours. In this case, the value of R would need to be re-calculated for as current of, say, 10mA. You would then need to check that it did not exceed 40mA when the battery was new. It should now be clear why an LED will not operate from a supply less than 2V - the necessary 2V could not exist across it.

The blues

Blue LEDs are now freely available although they were a very expensive item only a few years ago. Even so, they are still more costly than red, yellow and green types. Blue LEDs have a much higher forward voltage drop, about 3V in practice, so the supply voltage must exceed this. When using Ohm's Law to find the value of the series resistor needed, this increased forward voltage drop must be taken into account. Blue LEDs generally need between 20mA and 40mA to provide a good light output.

Some LEDs have a series resistor connected internally to save the trouble of using an external one. This is useful for specific purposes but these LEDs have limited experimental use because the fixed value of the internal resistor makes them suitable for only a small range of voltages. The most common are 5V and 12V types. Some LEDs have an additional section which limits the current over a wide range of voltages. Thus, the correct working current flows when it is connected to any supply between, say, 3V and 12V. Again, no series resistor is needed. This type of device is not available from all suppliers and is more expensive than the standard type. One of these would be useful when the indicator needs to glow at a steady brightness despite wide variations in supply voltage.

Around the Corner

The industry news that is grabbing headlines as we write is the link-up of network giant Oracle, gargantu-corporation Microsoft and the legendary Apple Computer, who brought us the early Apple II of fond memory and the user-friendly Apple Macintosh.

Apple has announced that Microsoft has bought $150 million-worth of non-voting stock in the company that looked as though it had lost the race in the market, and that Oracle's Larry Ellison, a keen opponent of the PC culture and exponent of all things networking, was to join the board of Apple Computer.

Why the sudden co-operation between business rivals who are quite good at taking care of themselves? Today, desktop PCs are the world's most popular computer, and Apple Computer has been struggling. And Oracle's massive database business is second only to Microsoft in the world software development market. Mr. Ellison was seen at one demonstration allowing a personal computer to tumble to the floor, apparently to make the point that network computers, sharing each other's resources, not personal computers, were the future. At least he didn't have one dropping from a second-floor window into a skip - yet.

But now Larry Ellison and Bill Gates of Microsoft are associating themselves with Apple, a rival but a trailing one. It's been reported that Larry Ellison believes that Apple software, which has led the way in developing front-end graphical interfaces for software users, is the right approach for the network computer that he is developing.

Meanwhile, Bill Gates still does good business providing software for Apple customers, particularly Mac users. Apple may be a niche company compared to Microsoft, but it is a niche that has provided some highly popular innovations over the years, and commands strong loyalty from its users, especially anyone who works with images, design and graphics.

Format-to-format has always been one of the sticking points of computing, and even hardened PC users had to admit that the Macs in offices had the right software and were converting PC files without too much difficulty long before the adjacent PCs were accepting files from the Macs. This was partly down to user demand: Mac users tend to be designers, and they know they have to load files from diverse sources.

Meanwhile, Microsoft also has a firm eye on the network market. Already closely associated with Internet software, Gates of all people knows that the isolated computer will surely and with increasing swiftness be out-evolved by networks, whether wired peer-to-peer networks, the modem-linked Internet, or platform-independent, Java-driven client/server "intranets". Computer will speak to computer.

We have already heard this year that the Labour Government is committed to connecting up British schools to the Internet at favourable rates to prepare children for the future. It looks as though parents of certain 15-year-olds who want to know why the family computer (the one you fondly thought was yours) isn't yet on the Internet will soon be able to argue "Don't you get enough of that at school?"

But this is not just business, and not just a game. The implication for everyone out there is that ETI readers, our families, our descendants, and possibly our grannies too, will in 10 years' time quite likely be doing a large part of our shopping, work and business on one machine talking to another machine. And converting from one program to another, and one format to another, is one of the big sticking points for computer users. The more the current leaders now can co-ordinate their efforts, and their formats, into one universal system, the better the chance they have of capturing and keeping this world market. And of out-evolving any challengers.

Next Month...

Volume 26 no. 11 of Electronics Today International will be in your newsagent on 10thth October 1997 ... We have been looking at the rapidly developing science and art of Digital Signal Processing ... Robert Penfold has built a 100 Hz to 10 kHz Total Harmonic Distortion Meter ... Tim Savage has been working on a Mk II Auto-Checker for continuity checking around the car, but also with household uses ... Pei An describes a radio digital data control system which can be used for home automation applications ... all the regulars, and more.

Contents are in preparation but are subject to space and availability.

Published by
Nexus Special Interests Limited
Nexus House, Boundary Way,
Hemel Hempstead, Herts HP2 7ST
Tel: 01442 66551
Fax: 01442 66998

EDITORIAL

Editor
Helen Armstrong

Administration Assistant
Lynn Bugden

Consultant
Andrew Armstrong

PRODUCTION

Designer
Dan Sturges

Technical Illustrator
John Puczynski

Production Executive (Copy control)
Marie Quilter

Printed By
Wiltshire Ltd., Bristol

Origination by
Atelier, St. Austell

SALES

Advertisement Manager
Andrew Forder
01442 66551 x331

Group Sales Manager
Jason Wollington

MANAGEMENT

Divisional Managing Director
John Bridges

Business Manager
Stuart Cooke

Senior Editor
David Watkins

Circulation Manager
William Pearson

Marketing Manager
Jason Doran

Copy Sales Manager
David Pagendam

SUBSCRIPTIONS

UK:Orders 01858 435344
Enquiries 01858 435322
USA: Wise Owl Worldwide Publications, 4314 West 238th Street, Torrance, CA9050545009 USA. For VISA/Mastercard orders phone: (310) 375 6258. Fax: (310) 375 0548. Pacific Time: 9am - 9pm weekdays 10am - 6pm weekends Visa/MC/Discover accepted.

READERS SERVICES
Back issues(last 12 months) £3.20 per issue if available. Photocopies of older articles often available. Write to The Photocopy Service, Readers Services Department, at Nexus House, Boundary Way, Hemel Hempstead, Herts HP2 7ST. Binders for ETI: £7.50 each including UK post and packing. Overseas please add £1.50. Cheques to Nexus Special Interest at Nexus House, or phone VISA/Mastercard orders to Readers Services Department 01442 66551

FOR ENTHUSIASTS • BY ENTHUSIASTS •
NEXUS

© Nexus Special Interests Limited 1997
All rights reserved

ISSN 0142-7229

The Publisher's written consent must be obtained before any part of this publication may be reproduced in any form whatsoever, including photocopiers, and information retrieval systems. While reasonable care is taken in preparation of magazine contents, the publishers, editors and their agents cannot be held legally responsible for loss howsoever arising from errors or other published material.

More than 18,000 top quality products **bound** for the enthusiast

£3.45

MPS
MAPLIN PROFESSIONAL

Over 2000 new products

PLUS COMPLETE GUIDE TO ELECTRONICS, COMPUTERS AND MUCH MORE

01702 554000

MPS
MAPLIN PROFESSIONAL

THE COMPLETE CATALOGUE FOR ELECTRONICS

1997/8

September '97 – February '98

Visit our Web Site http://www.maplin.co.uk

MAPLIN 25 ANNIVERSARY 1972 1997

42 Local Stores Nationwide – 8 New
Save £50+ Vouchers Inside
2000+ New Products
Trade Prices
FREE DELIVERY*

BRITAIN'S BEST-SELLING ELECTRONICS CATALOGUE

Available from 1st September 1997

The 'must have' tool for DIY enthusiasts, hobbyists and students, amateurs and professionals in the world of electronics.

- Over 25 years experience
- 42 stores nationwide
- Same day despatch
- Order 24 hours a day
- Free technical support on 01702 556001
- Free delivery on orders over £30.00
- Over £50 worth of discount vouchers

Order now on 01702 554000

Available at: WH Smith, John Menzies or your local Maplin Store.

(Add 50p for P&P). Orders outside the UK please send £8.45 or 21 IRCs for Airmail in Europe or surface mail outside Europe. Send £16.00 or 37 IRCs for Airmail outside Europe to:
Maplin MPS, PO Box 777 Rayleigh, Essex, England SS6 8LU.

When ordering please quote priority Code MA016.